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SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

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Design Considerations of CinemaScope Film

By E. I. SPONABLE, H. E. BRAGG and L. D. GRIGNON

This paper pertains to a new design of 35mm film for release purposes. The design was executed specifically for use in presentation of pictures by the CinemaScope system, but there is nothing which prevents the application of the film to other types of motion-picture methods. The essential features of CinemaScope film are a new, smaller perforation, and a change in the perforation transverse spacing. By this means, additional area is made available for a picture image of greater size than presently used, and for four magnetic soundtracks. The net result is an arrangement which makes for the maximum use of conventional width. The analyses, reasoning and other considerations which culminated in the design described are given in detail.

CINEMASCOPE identifies a particular combination of wide-screen picture and stereophonic sound, the wide-screen picture being produced by special optical means, mainly by the use of anamorphic lenses. For good practical reasons, obvious to those in the film industry, it is clear that picture and sound must be combined on one film, preferably of 35mm width, if such a system is to meet the requirements of all theaters.

CinemaScope was engendered by the competition by television and other competitive demands for the public's leisure time, as evidenced by the rapid closing of theaters — several thousand in one year — and by the obvious interest of the public in new forms of presentation, such as 3-D. It was presented as a possible means to encourage the motion-picture theater public to return to the theater, and to restore prosperity to the producer and exhibitor alike.

In proposing such a system, the first consideration was that in every aspect it should represent an advance in the art, today; and provide a sound basis for growth and improvement, tomorrow.

Wide-screen pictures, with aspect ratios greater than 1.75:1, require the maximum possible frame area if definition is to be maintained at a satisfactory level. Simultaneously, space must be made available for the three or more tracks required for the reproduction of true stereophonic sound. The primary problem, as far as this paper is concerned, is that of providing, if possible, the necessary increased film area.

Critical examination of many suggested possible solutions of the problems revealed three likely means by which the objective could be met: (1) reduce the film area required for the perforations, (2) use the film area outside of the perforations and (3) devise some means to use soundtracks of minimum width.

Presented on May 4, 1954, at the Society's Convention at Washington, D. C., by E. I. Sponable (who read the paper), H. E. Bragg and L. D. Grignon, Twentieth Century-Fox Film Corp., 444 W. 56 St., New York 19.

(This paper was received on May 18, 1954.)

Perforations

A very large amount of analytical study was given the overall problem of making the most efficient use possible of the standard film width. Each elemental area was considered in the light of its present up-to-date physical characteristics, and with respect to the function it is called upon to perform in modern projectors. One outstanding area which now seems unnecessarily large for its job is that assigned to the film perforation.

The film perforation dimensions, particularly the transverse width, were determined many years ago and have stood the test of time splendidly, but were dictated by circumstances quite different from those which exist today. Certainly, the factors which principally specify perforation design are film durability, sprocket wear, film shrinkage, manufacturing tolerances, tolerance of field equipment adjustment and registration ability.

Perforation design starts by considering the width of the sprocket-tooth face. Once this dimension is determined the width is computed by adding allowances for corner radii, shrinkage and manufacturing and field tolerances. A tooth width of 0.040 in. was selected, based on the opinions of projector design engineers and confirmed in tests, as the best compromise of all factors such as wear characteristics, ease of manufacture and a minimum of change in tooth shapes.

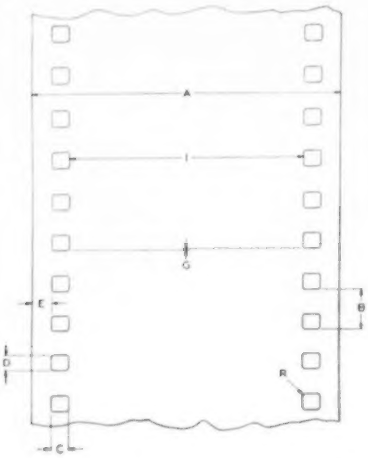
The performance of the Dubray-Howell perforation (ASA PH22.1) has been excellent both from the standpoint of wear and registration ability; therefore two dimensions, the corner radius and height, were borrowed from this well known design. There are good reasons for this choice, other than that of past performance: first, the small corner radii (0.013 in.) permit a hole of lesser maximum width, or alternatively, a sprocket tooth of greater relative width, without interference between the corner radius and the sprocket tooth; second, the somewhat reduced height provides a better proportion of hole dimensions.

Shrinkage data on the new triacetate-base materials were used; nitrate-base films which have not reached their end point of shrinkage would also be satisfactory but badly shrunk base is unacceptable. The manufacturing tolerances taken into account pertain to (1) transverse spacing of perforations; (2) center-to-center distance, transversely, of sprocket teeth; (3) dimensions of each perforation; and (4) the accuracy of alignment of the projector film-guiding means and the intermittent sprocket. Some modest advantage can be had by assuming that all tolerances will not add up simultaneously in the same direction; the advantage gained by this statistical device is assigned to field alignment of the gate and the intermittent sprocket and to abnormally shrunk film.

The result of the above reasoning is a perforation 0.073×0.078 in. with a 0.013-in. corner radius. Simple mechanics will illustrate that this design is basically better than the previous designs. Consider the following: the edge of the perforation which engages the sprocket-tooth face may be imagined to be an unloaded beam, until being driven by a tooth, then, being elastic the edge bends in two ways, in the plane of the film and away from the film plane. With either form of bending the tooth must actually engage and perform most of the driving function at the extreme edges of the tooth face. There are, of course, other factors which determine potential strength but the transverse width is certainly of great importance.

If the perforation pitch is to be unchanged, only one dimension, the center-to-center transverse spacing of the perforation remains to be considered. Manifestly, the theater must be prepared to project product on old standards as well as any new design; the equipment change must be simple and inexpensive and, preferably, require no interchange of apparatus for the different prints. If a transverse spacing of the perforations is chosen so as to locate the perforations near the outer edge of existing perforations a sprocket designed for CinemaScope film will operate satisfactorily on existing film standards. Specifically, the point of tangency of the outer corner

radii to the transverse driving edge of CinemaScope perforations corresponds to the similar point of tangency of standard positive perforations. The result is a center-to-center spacing of 1.127 in. as compared to the existing standard of 1.109 in.



DIMENSION	INCHES	MILLIMETERS
A	1.377 ± 0.001	34.98 ± 0.03
B	0.1870 ± 0.0005	4.750 ± 0.013
C	0.078 ± 0.0004	1.98 ± 0.01
D	0.073 ± 0.0004	1.86 ± 0.01
E	0.086 ± 0.002	2.18 ± 0.05
G	NOT > 0.001	NOT > 0.025
I	1.049 ± 0.002	26.62 ± 0.05
L	18.70 ± 0.015	474.98 ± 0.38
R	0.013	0.33

"L" DIMENSION REPRESENTS THE LENGTH OF ANY 100 CONSECUTIVE PERFORATION INTERVALS

Fig. 1. CinemaScope 35mm film standard.

Figure 1 gives the selected dimensions for CinemaScope perforations on standard 35mm film widths. Comparisons with film standards will illustrate that considerably more film area is made useful for picture. A comparison with film per ASA Z22.36 is given in Fig. 2.

Soundtracks

Since the whole basic theory of CinemaScope was to provide a sound technical basis for improved motion-picture presentations, and further to provide possibilities of continued improvement, it quickly became apparent that the panoramic, peripheral-vision-occupying type of picture required absolutely an equivalent improvement in sound, both as to improved response and enhanced reality of direction, spatial distribution and encompassment.

Stereophonic recording techniques were already developed and at hand.

One manner by which the multiple-track requirement of stereophonic sound can be met with track widths smaller than past optical track practice is to take advantage of the superior performance of magnetic recording technique. Additionally, the simplicity of reproducing equipment makes magnetic sound methods especially attractive because of lower cost and ease of maintenance. It is known that magnetic tracks of 0.050 in. in width can give results which are superior to any of the conventional release-print optical tracks. Allowances for weave and variations in track width dictate a magnetic track 0.060 to 0.065 in., if 0.050 in. is to be scanned in the reproducer.

Soundtracks must not be placed so close to perforations that intolerable 96 cycles/sec modulation occurs due to film distortion, but although past practice has required that tracks be placed at least 0.050 in. from perforations, and this is still considered good studio policy,

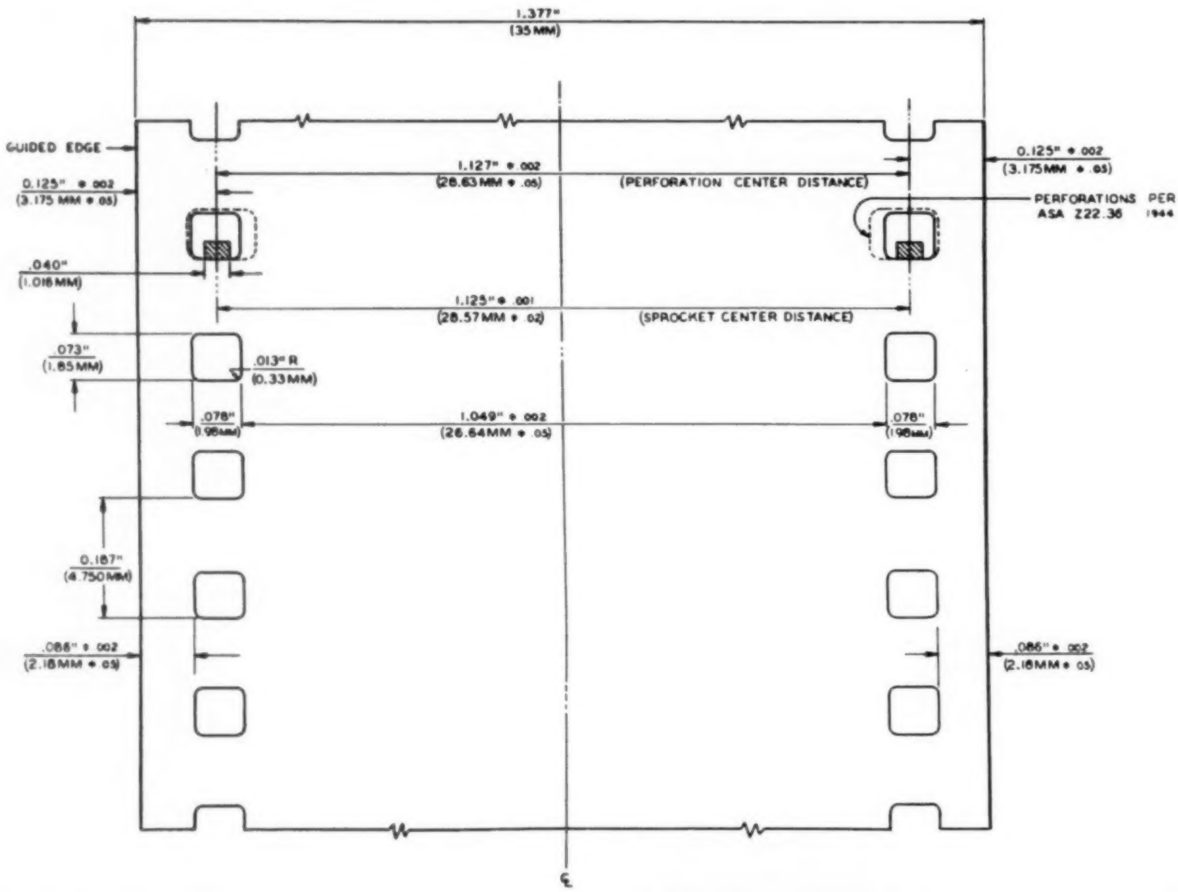


Fig. 2. CinemaScope standard perforations compared with ASA Z22.36–1944 positive perforations.

it has been found satisfactory to place the magnetic tracks 0.015 in. from the holes for release prints. Therefore, with this line of reasoning, there is enough space outside the film perforations for two tracks, one on each side of the film. Some allowance must be made for rounded-off edges of the track and for clearance from the film edge to minimize shredding by projector mechanisms. The net result of all these considerations is tracks 0.063 in. in width. For three-channel stereophonic sound one additional track is required which should have performance characteristics identical with the other two. This track can be placed inside one row of perforations symmetrically located in reference to the perforation with one outside track.

An additional sound-reproduction facility has been provided with CinemaScope. This is a fourth soundtrack, of somewhat lesser technical performance than the three principal tracks, for use as a control signal track and/or a sound-effects track to be reproduced on auditorium, or surround, loudspeakers in the theater. This fourth track of 0.029 in. in width is placed 0.010 in. inside the second row of perforations. The use of this feature provides sounds for increased audience participation in the theater.

Figure 3 shows CinemaScope film with the magnetic tracks applied thereon. The magnetic sound scanning gaps may also be seen.

Apertures

In effect, the two inside soundtracks may be regarded as the transverse extremes of the print image frame, and serve in a sense as the printer aperture. The projector aperture must of course be smaller to allow for weave, registration errors and soundtrack-placement errors. Figure 3 includes the projector aperture for head-on projection. It will be noted that 0.010 in. is allowed inside each soundtrack. Although this is a smaller tolerance than has been previously provided it is believed that the state of the art now permits projection within these limits. The anamorphic attachments used with CinemaScope have a magnification of 2 in the horizontal plane, therefore the frame height is computed by dividing twice the frame width by the aspect ratio. In CinemaScope, the aspect ratio is 2.55 and the projector or aperture size is, as shown in Fig. 3, 0.715 × 0.912 in.

The frameline width of 0.033 in. is less than the overlap of either the negative splice of 0.040 in. or the positive splice of 0.070 in. If the projector aperture is full frame height and the screen masking does not extend into the screen picture, splices will be momentarily visible. Generally, the masking intrudes upon the picture somewhat and the splice is seldom apparent to the audience.

The camera aperture must be somewhat larger than the print frame to guarantee clean edges and therefore has been specified as 0.735 × 0.937 in. with

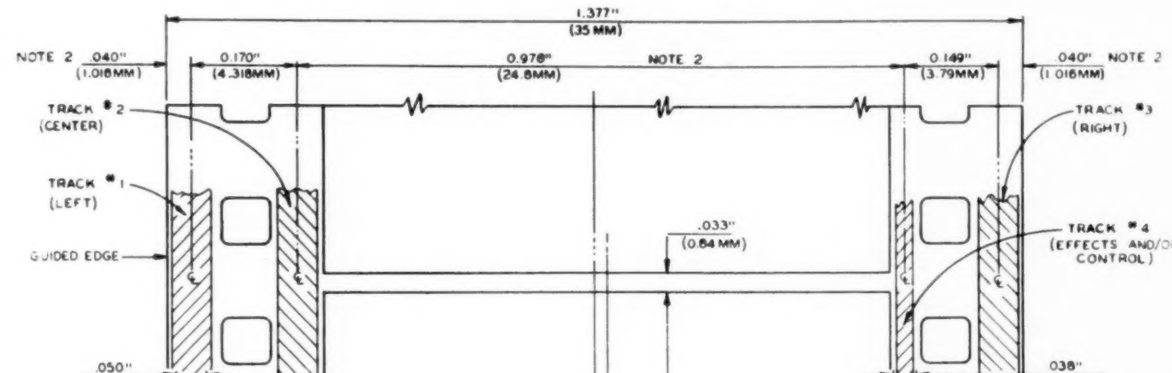


Fig. 3. CinemaScope release film standards — picture and sound.

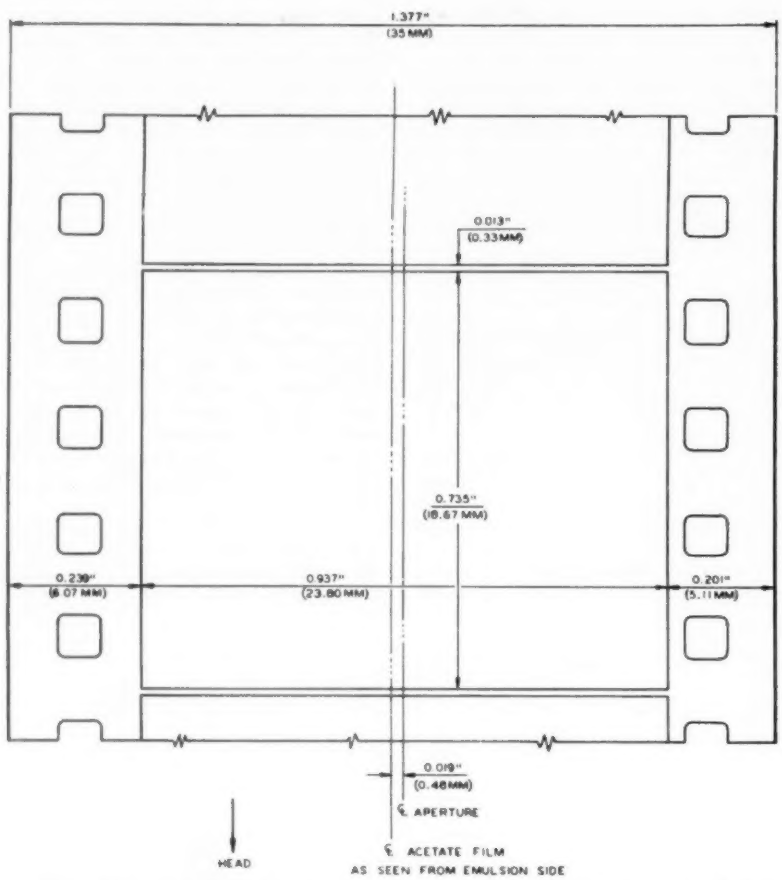


Fig. 4. CinemaScope camera frame dimensions (shown with CinemaScope perforations).

a 0.013-in. wide frameline. This is shown in Fig. 4. The small frameline imposes a strict requirement upon the placement of the camera aperture with respect to the perforations, but this is no hardship on the industry at large since cameras are customarily made to very close tolerances and they are relatively few in number.

The printer aperture is not specified herein. Without optical tracks the dimensions of the aperture are no longer critical; as a matter of fact, the negative can be printed full aperture.

Performance

The question as to film durability is invariably asked. Comparative life tests, under controlled and reproducible conditions, have been made with existing standard films and with CinemaScope. Every test has shown CinemaScope film to be at least the equal of the older types and if the recommended CinemaScope sprockets are used, the life of CinemaScope film is three to four times as great as can be expected from former standard practice. The considerable improvement in wear derives principally from the use of intermittent sprockets having a base pitch diameter of 0.953 in. rather than the present recommended 0.943 in. (Dimension B, ASA Z22.36). Although many tests have always confirmed the value of overpitched sprockets, their adoption has been slow indeed. A change in standards, such as CinemaScope represents, supplies the opportunity to make good use of the knowledge at hand. The use of magnetic tracks has undeniably provided the means for improved sound reproduction in the theater and the use of stereophonic sound has certainly increased the realism of the presentation. No serious field problems have yet arisen in servicing theaters with more than 25,000,000 ft of release prints.

Acknowledgments

Several organizations, and their personnel, were most helpful during the initial stages of this integrated project, principally the following: Altec Lansing Corp., Bausch & Lomb Co., Brush Electronics Co., Eastman Kodak Co., General Precision Laboratory, RCA Manufacturing Co., Reeves Soundcraft Corp. and Westrex Corp.

Observer Adaptation Requirements in Color Photography and Color Television

By RALPH M. EVANS
and W. LYLE BREWER

Observer reactions are the final criteria in determining if a color photograph adequately reproduces a scene. These reactions indicate that ordinary colorimetric measurements cannot serve as the sole indication of reproduction quality. Dependence of the state of observer eye adaptation on viewing conditions has been found to overshadow simple colorimetric considerations. Adaptation requirements in color photography have been met through application of the so-called "first and second black conditions." It will be found essential also in color television that the two black conditions be applied. In both color photography and color television, particularly the latter, a new interpretation of the two black conditions should further improve the color quality of reproduced scenes.

COLOR MIXTURE LAWS, which serve to indicate the types of radiant-energy distributions which will match each other, are embodied in the science of colorimetry. This science is well established and well understood. Colorimetry tells us that any two colors, or radiant-energy stimuli, having the same tristimulus values will match each other. Two stimuli having the same tristimulus values but different spectral compositions are called metamers. Except for pure spectrum colors, any color has many metameric forms. These metameric forms exist in such variety that given any one of a number of possible sets of three primary-color stimuli, all colors except those of exceedingly high saturations can be matched. This is indeed fortunate because on it depend all the important color-reproduction systems, including color photography and color television.

Instruments and computing procedures are available which enable us to determine the tristimulus values of any radiant-energy stimulus. This means that given any group of colors in a scene to be photographed or televised, we can determine the nature of the stimulus which must come from the photograph or the television receiver in order that the colors of the original scene be matched. Thus, it would seem, the requirements for the exact reproduction of a scene on either film or color television may be established with high precision.

In actual practice, however, it is found that the problem of matching color stimuli and the problem of obtaining a satisfactory reproduction of a scene are two different matters. The problem of reproducing a scene is that of obtaining color stimuli from the reproducing apparatus which "look like" those of the original scene. This is metamerism of a sort, but not what is usually meant by the term. The distinction between what we mean when we say that colors match and that they look alike can be illustrated by descriptions of two types of color-matching experiments.

Presented on October 8, 1953, at the Society's Convention at New York by Ralph M. Evans and W. Lyle Brewer (who read the paper), Color Technology Div., Eastman Kodak Co., Rochester 4, N.Y.
(This paper was first received on Oct. 16, 1953, and in revised form on Apr. 9, 1954.)

Color Matching and Adaptation

In Fig. 1 are illustrated the viewing fields of the type of colorimeter in which color-matching data normally are obtained. By means of filters, or in some other way, the test field is illuminated with light of a certain spectral composition. The matching field is illuminated with a mixture of red, green and blue lights, the amounts of which may be varied. These amounts are varied until the matching and test fields do not differ in appearance. The test and matching fields are enclosed by a surround or adapting field. In establishing the visual characteristics of the CIE standard observer, a completely dark surround was used. Except for precision differences, however, matching results are not influenced by the surround providing that it encloses both the test and matching fields. On the other hand, if the surrounding field is changed, the appearance of both test patches will change. Furthermore, if two patches are matched with like surrounds, they will no longer match if the surrounds are changed so that the two patches are separately encompassed by surrounds differing in appearance.

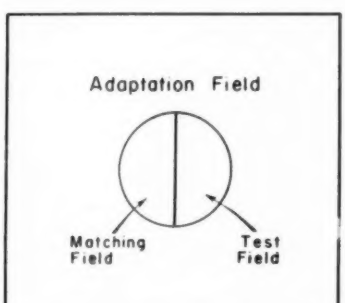


Fig. 1. Schematic diagram of the viewing fields of the type of colorimeter normally used in obtaining color-matching data.

The adapting conditions prevailing for viewing photographic film or television are seldom the same as those for the original scene. Furthermore, the adaptation conditions for any individual scene in a sequence of original scenes may be quite different from those of the scene before it or of the scene which follows. To be satisfactory, the colors of the reproduced scene must conform to those required by the adaptation conditions prevailing for the reproduction.

The Two Black Conditions

Color adaptation requirements as they apply to color photography appear to have been stated first in terms of the two black conditions. McDonough[1] recognized the first black condition in connection with his work on screen-plate processes. In a more complete analysis of screen-plate processes Mees and Pledge restated the first black condition and added the second black condition.. As given by Mees and Pledge the two conditions are:[2]

First Black Condition: "In order that whites should be rendered untinged by colour, it is necessary that the screen itself when examined should appear to be free of colours, i.e., of a neutral shade."

Second Black Condition: ". . . it is necessary that a grey, to be correctly rendered, should produce an equal deposit [of silver] under each of the three filter units."

According to the first black condition the screen elements of a screen-plate process should be combined together to form a neutral. The term neutral applies to an object which does not alter the chromatic characteristics of the illumination incident upon it. The object may be spectrally selective or nonselective but to be neutral its chromaticity must be the same as that of the illumination. To satisfy the first black condition, therefore, the integrated effect of the combination of red, green and blue

filter elements of the screen plate should be such as not to alter the chromaticity of the light transmitted by the screen plate.

The second black condition states that a gray of the original scene should result in equal deposits under the three colored filter elements of the photograph. The term gray applies to any one of a series of colors, varying in brightness, between the limits of white to black. It may be applied to an object or to the light stimulus coming from the object. Studies to determine the nature of the light stimulus which will appear as gray or white have usually been confined to stimuli along the black-body locus. The color temperature of the light which, on the average, appears to be most acceptable as white is about 5200 K.[3] Much depends, however, on the particular observer, the state of adaptation, and the intensity of the stimulus.[4] Light from any illuminant in the color-temperature range of about 2800 K to 10,000 K will be acceptable as white if it is of reasonably high intensity and, particularly, if this light is the primary factor in controlling adaptation. Thus, if the major source of illumination for a scene is a tungsten lamp of relatively low color temperature or any one of a number of different forms of daylight of relatively high color temperature, the light from this source may be considered achromatic.

In a scene illuminated by light which, as just described, is achromatic, the application of the terms white and gray to objects is apparent. A white object has high reflectance and high diffusion and the light it reflects has the same chromaticity as the light incident upon it. A gray object is chromatically like a white object. It differs from a white object in appearing to have a lower reflectance.[5]

Taken together the two black conditions state that a gray object in the original scene should be reproduced as a neutral area in the screen plate photograph. This neutral area, upon projection, should appear as a gray in the photograph. Thus, a gray should be reproduced as a gray. The chromaticities of the two grays will not necessarily be the same, however. The chromaticity of the gray in the original scene will be that of the prevailing illumination in the original scene; the chromaticity of the gray in the photograph will be that of the projection illumination. Similarly, a white of the original scene should be reproduced as a white in the photograph

Subtractive Photography and Television

The two black conditions as originally given refer only to screen-plate processes but they can be generalized to include subtractive color photographic processes and color television. For subtractive color photographs the black conditions indicate that a neutral combination of dyes in the photograph should be obtained for any object which is gray or white in the original scene. Red, green and blue exposures which give a neutral combination of dyes are considered equal to each other. Gray and white objects should therefore give equal red, green and blue exposures.

For each family of film products there is normally one type of film for daylight and one type for incandescent tungsten light. The tungsten-light film is usually identified in terms of the particular color temperature for which it is designed. Each type of film is "balanced" so that approximately equal red, green and blue exposures are obtained for light of the spectral quality of its illuminant. At best, the different types of film can be balanced for only a few of the "average" illumination conditions. Additional types would provide for better color balances in the photographs but would necessarily be less convenient and more expensive. Filters over the camera lens can, of course, provide balancing for a wider variety of illuminations.

As applied to color television, the implication of the first black condition is that (1) each television receiver should be capable of giving a white at a luminance equal to or higher than that for any other color, and (2) the white should be fixed in chromaticity, regardless of the scene from which it is derived. Grays should be of this same chromaticity, differing only in luminance.

The second black condition implies that the R, G and B television signals corresponding to those which ultimately control the red, green and blue phosphor excitations should all be equal to each other for a gray of the original scene. It is convenient to normalize the R, G and B signal values so that each equals 1.00 for the highest luminance white. For a gray R, G and B would have smaller values, but would be equal to each other.

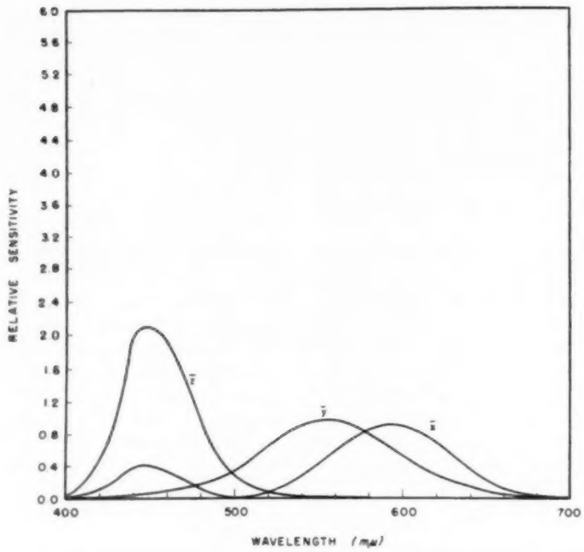


Fig. 2. Required effective relative spectral sensitivities of receptors of television camera conforming to CIE distribution coefficients, $\bar{x}$, $\bar{y}$ and $\bar{z}$, balanced for artificial daylight, CIE standard Source C.

The requirements of the second black condition can probably be more easily and more fully met in color television than in color photography. Periodically a white or gray object should be placed in front of the camera and illuminated by the prevailing illumination. If there is more than one type of illumination, the chosen illumination should be that which is considered predominant. The voltage outputs of the three signal channels should then be balanced to equal each other. In going from daylight to artificial light, marked changes will be required. In televising an outdoor event, such as a football or baseball game, it will be desirable to rebalance periodically as the azimuth of the sun changes or as cloud formations result in greater or lesser effective contributions of skylight to the illumination.

The general order of magnitude of the changes is illustrated in Figs. 2 and 3. For purposes of illustration it is assumed that the effective relative-sensitivity distributions of the three camera receptors are the same as the distribution coefficients, $\bar{x}$, $\bar{y}$ and $\bar{z}$, of the CIE observer. The sensitivities are balanced for CIE Source C, which conforms reasonably well with average daylight. The areas under the curves in Fig. 2,

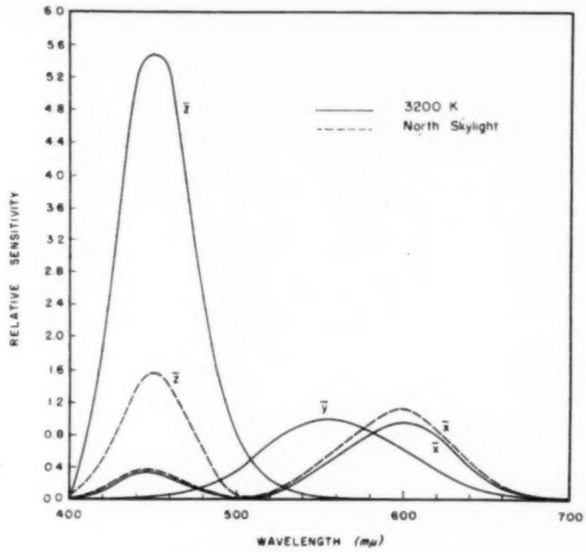


Fig. 3. Required effective relative spectral sensitivities of receptors of television camera conforming to CIE distribution coefficients, $\bar{x}$, $\bar{y}$ and $\bar{z}$, balanced for an illumination of 3200 K (——), and balanced for north skylight (---).

weighted by the spectral energy distribution of Source C, all equal each other. The $\bar{y}$ curve in Fig. 3 is the same as in Fig. 2. The other two curves have been multiplied by constants such that the three are then balanced for 3200 K. This illumination corresponds fairly well to normal tungsten illumination. Balance for a type of skylight[6] is illustrated by the broken-line curves in the same figure.

The changes in effective sensitivities illustrated for three illuminants in Figs. 2 and 3 are indicative of those necessary for conformance to the second black condition. Changes of this order of magnitude will be found necessary (for the illuminants illustrated) and, if made, will probably be found to give satisfactory results.

Adaptation and Fundamental Response Functions

As originally stated, generally interpreted, and as illustrated here, the two black conditions have specific reference only to achromatic colors. To develop more general principles which take chromatic as well as achromatic colors into account it is necessary to study pairs of color stimuli which match each other when the two members of each pair are seen under different states of observer adaptation. One means of doing this is through binocular matching experiments. The type of experiment is illustrated in Fig. 4. One color field, which may be considered as the test field, is viewed by the right eye, and the matching field is viewed by the left eye. The test and matching fields are so arranged that they appear juxtaposed. Separately controlled adaptation fields surround the two fields. Suppose that initially the two adapting fields are made the same and the matching field is adjusted to match some given stimulus in the test field. Except for differences in the characteristics of the two eyes, the results obtained in this type of matching experiment are the same as for normal color matching. If the surround for the left eye is then altered in color, the match will no longer hold. By readjustments in the matching field a new match can be obtained. If the differences in the adapting fields are fairly large, the change in the matching field necessary to obtain the new match is also apt to be large.

The validity of the binocular matching technique has been attested by Wright.[7] His findings indicate that if artificial pupils are used in the colorimeter the adaptation interaction effects between the two eyes are sufficiently small to be neglected.

In a series of color binocular matching experiments Burnham, Evans and Newhall[8] determined a number of pairs of stimuli which would match where one member of each pair was seen under Illuminant A and the other under Illuminant C. By means of a computing procedure described by Brewer,[9] curves were obtained which, within the limits of precision of the original data, correspond to the fundamental response functions of the eye. The curves so determined are shown in Fig. 5. Although high accuracy for these curves cannot be claimed, it is possible by means of them to indicate the nature of the sensitivity changes required in film and in television cameras to fulfill adaptation requirements.

For example, suppose initially a television system is balanced for taking and viewing with adaptation to CIE Source C. Assume also that the effective spectral response characteristics of the camera conform to those of the CIE X, Y, Z system. A change in scene to one giving adaptation to 3000 K would then require camera spectral sensitivities conforming to those of the solid lines of Fig. 6. A mere rebalance of camera sensitivities, keeping the same relative distributions as the standard observer distribution curves, would give the broken-line curves. Differences between the two sets of curves arise because the rebalance in sensitivity distributions for the solid-line curves was taken by reference to the curves shown in the preceding figure, Fig. 5. This is equivalent to stating that color adaptation may elevate or depress each of the fundamental response curves, but cannot change its relative spectral distribution.

The areas under the solid-line curves of Fig. 6, when weighted by the spectral distribution of the 3000 K illuminant, are equal to each other. The same is true for the broken-line curves. In this sense the two are equivalent; both fulfill the requirements of the second black condition. They differ in that the solid-line curves are designed to take into account the phenomena of color adaptation as they apply to a wide variety of colors.

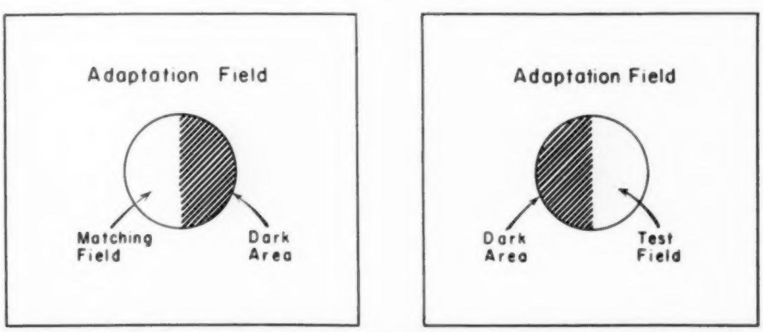


Fig. 4. Schematic diagram of the viewing fields of a binocular colorimeter in which the two eyes can be differently adapted. Left: left eye; right: right eye.

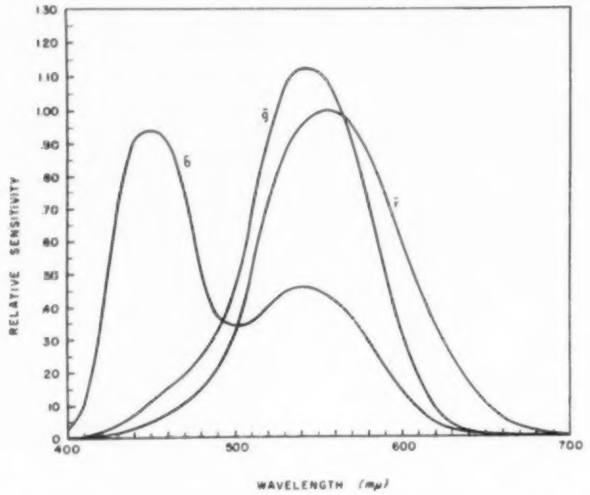


Fig. 5. Fundamental response curves of the eye as determined from a binocular color-matching experiment.

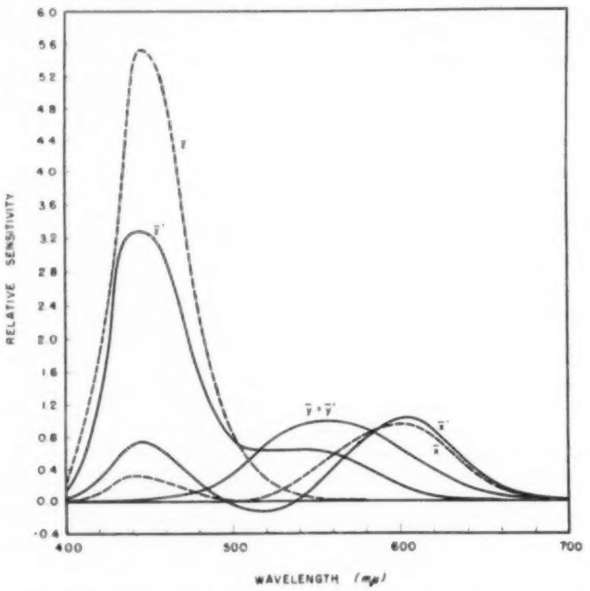


Fig. 6. Camera-sensitivity distributions expressed in terms of CIE *X*, *Y*, *Z* primaries which (solid line curves) are balanced in terms of fundamental response functions for 3000 K, and (broken line curves) are balanced directly in terms of $\bar{x}$, $\bar{y}$ and $\bar{z}$ CIE distributions.

The broken-line curves correct properly for the scale of neutral colors but are less satisfactory than the solid-line curves for other colors. Receptors with sensitivities conforming to the solid-line curves should therefore provide for closer agreement in appearance between colors of the original scene and those of the reproduction.

Results equivalent to those obtained by altering the effective sensitivities may also be obtained without altering the actual receptor sensitivities provided that the signals from the receptors are suitably modified. For example, the effect of multiplying any camera-sensitivity distribution by a constant can be obtained by leaving the actual sensitivity unchanged and adjusting the gain on the signal output according to the value of the constant. Similarly, the more complete corrections indicated by the solid-line curves of Fig. 6 can be obtained by linear matrixing. Let X, Y and Z denote the signals as they would be obtained for balance to CIE Source C. If a change in adaptation illuminant is made to 3000 K, the same camera sensitivities could be used, but the signals going through the remainder of the system should be modified to X′, Y′ and Z′ where:

$$\begin{aligned} X' &= 1.13\,X - 0.31\,Y + 0.17\,Z \\ Y' &= 0.01\,X + 1.00\,Y - 0.01\,Z \\ Z' &= -0.23\,X + 0.69\,Y + 1.89\,Z \end{aligned} \qquad (1)$$

Equations (1) and the curves of Fig. 6 illustrate means of conforming to the two black conditions in such a way as to take adaptation phenomena into account. They are based upon the fundamental response functions as determined from one particular investigation. The true response functions may prove to be different from those illustrated and, if so, the curves and the equations would be different. As a first approximation, however, those given are probably reasonably correct. The curves and equations given also apply to only one pair of adapting illuminants and are expressed in terms of a particular set of primaries. Given the set of fundamental response functions, however, corresponding curves and equations can easily be determined for any pairs of illuminants and for any system of primaries.

Summary and Conclusions

Successful operation of any color-reproduction system such as in photography or television is dependent upon conformance to the two black conditions. Adequate conformance can probably be obtained by adjusting the three effective film or television-camera sensitivities for balance to the prevailing illumination, with a single form for each of the spectral sensitivity curves. The two black conditions are necessary because of observer visual characteristics which are associated with color-adaptation phenomena. Conformance to the two black conditions in such a way as to best take into account color adaptation would require that all rebalancing for adaptation-controlling illuminants be made with reference to the fundamental response functions.

Increased fidelity of reproduction through reference to the fundamental response functions is obtainable only at the expense of greater complications in the reproduction system. The necessary corrections in color television could probably best be obtained through replaceable or continuously changeable matrix units. The gains possible by means of these more complicated systems would probably be worth while only for a reproducing system which is in excellent adjustment and where high fidelity of reproduction is believed to be very desirable. Either in this fashion or by the simple means of relative readjustment of the three signal components, however, conformance to the two black conditions is essential.

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Discussion

Peter Krause (Ansco): Could you tell us if the data that you plotted were obtained from binocular matching?

Dr. Brewer: The data from which the curves were derived were obtained from binocular matching.

Mr. Krause: What was the aperture of the instrument, that is, the exit pupil of the binocular instrument that was used in making the observations?

Dr. Brewer: A description of the instrument has been given by Burnham, Evans and Newhall in the Journal of the Optical Society of America, vol. 42, pp. 598–600 (1952). The test and matching fields were each 1 × 2 degrees in subtense. The surrounding adapting fields subtended about 40 degrees.

Mr. Krause: Would you know how many observers were involved in obtaining the data?

Dr. Brewer: A number of observers were involved in the binocular matching experiments. This particular set of data was based upon a single observer. The matching experiments are being repeated with different sets of adapting illuminants in the hope of obtaining more extensive and precise data.

R. P. Burr (Hazeltine Corp.): My understanding is that this analysis relates to a television system which is considered to be linear in terms of brightness from input to output. How would you evaluate this analysis in terms of the fact that most reproductions which people consider to be pleasing pictures generally deviate very substantially from a linear transfer characteristic and frequently have an S-shaped transfer characteristic? The question is asked because this sort of work bears on the final specification of gamma correction or the nonlinearity correction in the television system.

Dr. Brewer: I would not agree with your starting premise that our analysis is based upon an assumed linear system. The main thing is that the three H or D or transfer characteristic curves match each other. If one of them is straight, the other two should be straight; if one of them is curved, the other two should be curved in exactly the same fashion. In practice these curves are not linear for screen plate photographic processes, for subtractive photographic processes, or for color television. Linearity is neither obtainable nor necessarily desirable. The requirement is that, regardless of the shape, the three curves be as closely matched as possible.

Mr. Burr: That pretty much answers the question. I believe that what you have said in effect is that if you could do what you described for color photography you would be very happy.

Proposal of a Performance Rating for Projection Screens

By GERHARD SCHWESINGER

The lack of a general performance criterion for projection screens is regrettable, particularly in view of recent advances in screen design. In this paper a performance rating is proposed which is based on empirical results as well as theoretical considerations. It does not stress a particular property of the screen, but rather the interaction of several factors determining the overall performance. It is shown that the new criterion gives an unbiased rating of screens of widely diverse characteristics. Its effectiveness is demonstrated by concrete examples. In the application to a class of absorbing screens, certain limitations may exist whose analysis calls for further experimental evidence. The results discussed reveal the surprisingly large margin left for possible improvements in screens.

The importance of having some suitable criteria for rating the performance of projection screens is more and more recognized. Because of the diversity of available screen types and their widely varying characteristics it is not easy to suggest a criterion that is simple, reliable and applicable to all screen surfaces of practical importance. This difficulty is reflected in the fact that the performance criteria suggested so far emphasize in general one particular property of the screen, but neglect others. For this particular property the criterion may be useful, as for instance the "shape factor" which has recently been proposed by A. J. Hill[1] for describing quantitatively the decrease of screen intensity with increase of viewing angle. Hill approximates the measured intensity curves by suitably selected cosine power curves and thus obtains simple relations from which screen brightness data can be analyzed, provided that the fit is good enough. However, the shape factor is a quantity which varies between wide limits, the minimum being unity, while the maximum, theoretically, is unlimited. One commercial diffusing surface evaluated in the present paper was found to have a shape factor of about 3700. When comparing two rear-projection screens with the same shape factor, one cannot conclude that these two screens represent about the same degree of technical achievement. In fact, if these screens have markedly different reflection and absorption losses, their overall performance will be rated quite differently when such properties as contrast rendition under ambient illumination are taken into account.

Other criteria stressing particular screen properties, such as brightness gain, are inadequate too when applied singly for the purpose of an objective screen rating which ultimately requires a complete set of specifications. E. W. D'Arcy and G. Lessman have discussed this problem in detail and set forth specific recommendations.[2]

If nothing short of a complete specification can serve for rating screens, any attempt at approaching this objective by specifying a single number, a figure of merit or the like, may seem overambitious. It must be recognized from the outset that such a figure of merit means a sacrifice of all specific informa-

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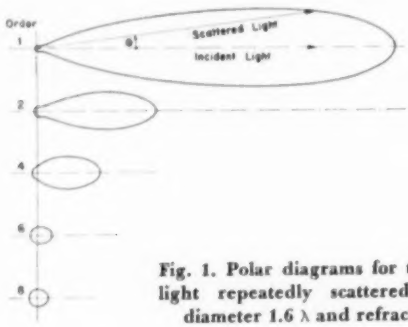

Fig. 1. Polar diagrams for the distribution of light repeatedly scattered by particles of diameter 1.6 λ and refractive index 1.25.[4]

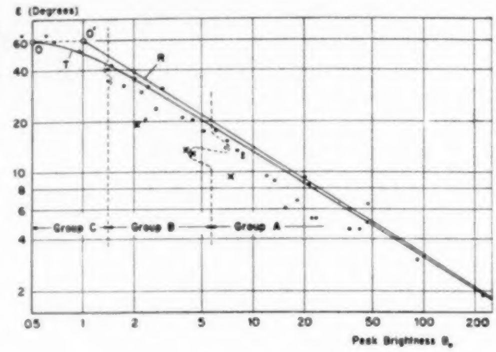

Fig. 2. Characteristic angle ε and peak brightness B_0 of diffusing screens.

tion such as can be drawn from other criteria like shape factor, brightness gain, etc. The figure of merit merely means that from a technical viewpoint a certain screen is a better product than some other with a lower figure, better in the sense that the maker succeeded to a higher degree in overcoming the difficulties and limitations which nature imposes on controlling fundamental processes. The figure of merit measures a technical achievement, not a physical property. A measure of this kind is much desired, however.

In this paper an attempt is made to establish and justify such a figure for projection screens. When based solely on theoretical considerations, a proposed figure of merit may appear somewhat speculative and lacking substance because the assumptions that must inevitably be made for convenience may easily produce meaningless results. A purely empirical approach, on the other hand, may arouse suspicion that the investigator was biased in selecting his material or failed in its correct interpretation because of obscuring side effects. Since the present attempt is based on theoretical considerations as well as empirical findings, it is believed that there is concrete substance in what underlies the proposed criterion.

Let the discussion first center on rear-projection screens with microscopically random surface or body structure and negligible absorption. The justification for deriving a single figure of merit for such screens seems to lie in the basic fact that the two most important screen characteristics, the angular brightness distribution and the surface reflection, are tied together by nature in a rather rigid manner. Knowing one of these characteristics, one can almost guess the other, or at least guess what it should be for an average screen. In order to understand this fully, it is necessary to consider briefly the fundamental processes which are responsible for the light diffusion in transmitting screens, namely refraction and scattering at boundaries with random surface irregularities or scattering by a layer of randomly distributed microscopic or submicroscopic particles.

Fundamental Diffusing Processes

As an example of the former case, consider a sanded or ground surface. The incident light hits a microscopic landscape of irregular depressions, the smallest elements of which, those of the order of the wavelength or smaller, scatter or diffract the light preferentially in the forward direction. This type of scattering will be discussed further in connection with layers of diffusing particles. The larger surface slopes, ten times larger than the wavelength or more, deflect the light by refraction, and this to a greater extent as their steepness increases. The intensity of the refracted light becomes small at large deflections for three reasons. First, the solid angle filled by the refracted light increases at a rate faster than the increase of deflection. Further, in a terrain of random shape steep slopes cover a much smaller portion of the ground area than flat ones. Finally, according to Fresnel's laws, steep slopes reflect a higher percentage of the light backward. As a result the screen brightness drops rapidly from a peak at zero viewing angle. In ground glasses, for example,[3] the drop to half of the peak brightness occurs within angles of only 2° to 15°. The larger half-angles are invariably accompanied by higher backward reflection.

There exists a remarkable relationship between the forward peak brightness B_0 and the brightness D_0 that is observed on the rear surface of the screen, in the direction of the incident light. In the following, the brightness of an ideal nonabsorbing diffuse reflector exposed to the same incident light will be taken as unity. Let now an angle ϵ be defined by

$$\cos \epsilon = B_0/(B_0 + D_0) \qquad (1)$$

If, then, on a screen of the type considered that screen brightness B_ϵ is measured which is observed at the particular viewing angle ϵ, it is found that the quantity

$$\alpha = \frac{B_\epsilon}{B_0} \cos \epsilon = B_\epsilon/(B_0 + D_0) \qquad (2)$$

is almost independent of the surface structure. Screens of widely different characteristics have roughly the same values of α, a trend toward larger values being shown by highly transmitting screens with pronounced "hot spots." In the Appendix, some theoretical considerations are given which lead to an identical conclusion.

It is interesting to note that the same general result is found for rear-projection screens consisting of a layer of scattering particles. Theory shows that the angular distribution of the intensity as well as the total amount of energy scattered by a spherical or nearly spherical particle of low absorption depends largely upon its size relative to the wavelength of the incident light. Particles that are small in comparison to the wavelength are inefficient scatterers and therefore impractical for light diffusion. Only if the particle size is of the order of the wavelength will a given quantity of scattering material produce an optimum effect. Particles of such size exhibit an intensity distribution of very complex detail, with many sharp intensity maxima and minima alternating in short succession. This detail changes rapidly, however, with particle size and shape so as to be blurred out in a large population. Curve 1 of Fig. 1, calculated by H. H. Theissing,[4] shows the remaining features, namely, a predominant forward scattering, a sharp drop of intensity off axis and very small backward scattering.

This typical hot-spot characteristic can be improved by having the lightwave scattered repeatedly before it leaves the scattering medium, either by means of a thicker layer or by increasing the particle concentration. Curves 2, 4, 6 and 8 of Fig. 1 are the resulting intensity distributions for second, fourth, sixth and eighth-order scattering, respectively. After the latter, the intensity is almost uniform; unfortunately, however, it is uniform all the way around so that as much light is reflected backward as is utilized forward. Scatterers of this type, for which opal glass is a practical example, are liable to exhibit poor image contrast because of increased stray light and high reflection of unavoidable ambient light at the front surface. This and other contrast-reducing factors have been discussed elsewhere.[2]

It can be seen that for scatterers of the last-mentioned type the above-defined quantity α assumes the value 0.5. For extreme forward scattering, as illustrated by curve 1, α is above 0.7. Within this range, α changes in a continuous manner. The general trend is the same as that found in the previous case of diffusion at an irregular boundary, as borne out by the table in the Appendix.

Proposal of a General Performance Criterion

From the foregoing considerations it appears that in both fundamental random processes of light diffusion the possibilities of uniform forward brightness and high transmission are mutually exclusive. This result is true in a rather strict and predictable manner as can be seen from Fig. 2 which is a plot of the characteristic angle ϵ versus the relative forward peak brightness B_0, both in logarithmic scales, for 37 diffusing materials of low absorption (heavy dots). The photometric data of these materials have been measured at the Massachusetts Institute of Technology[5] and the Signal Corps Engineering Laboratories. The plotted points scatter remarkably little from a curve marked T which represents the upper limit of the angle ϵ. The curve T has been so constructed as to pass through the encircled point O at $\epsilon = 60°$, $B_0 = 0.5$. This condition, according to Eq. (1), is representative of uniform absorption-free scattering ($B_0 = D_0 = 0.5$) as discussed in the preceding section. The screen plots show a tendency toward smaller values of ϵ as the absorption increases. Yet the converse is not necessarily true, that is, low values of ϵ are also found in some nonabsorbing screens. Exactly these screens rank highest in performance.

The few points plotted above curve T involve slightly inaccurate measurements.[5] It could be proved that for these particular screens the sum of transmitted and reflected light exceeds the incident light which is, of course, impossible.

The general relation shown in Fig. 2 may be taken as the starting point for establishing a performance criterion that does equal justice, from the viewpoint of technical achievement, to widely different screen characteristics. Consider two screens with characteristics like those illustrated by curves 1 and 8 of Fig. 1. Although too different to be suitable for the same application, they deserve about equal merit when looked upon as technical achievements because one and the same physical process could be controlled so as to produce these two different characteristics. It would be necessary only to change the thickness of a scattering layer or, in other cases, the coarseness of a diffusing surface. A change of this kind can hardly be rated as a higher or lesser degree of technical achievement, such as would be the reduction of a hot spot with no increase of the backward reflection.

On these premises, the quantity α could be regarded as an approach to a performance criterion. In the last-considered example of the two extreme scattering characteristics of equal technical merit, about the same numerical values near 0.5 would in fact be obtained. An ideal screen with flat characteristic and no loss ($D_0 = 0$) would be characterized by a unit value of α, as can be seen from the defining equations. The only objection to the figure α is the slight preference that it exhibits, according to theory, toward screens with hot-spot characteristics. This preference has also been established from the measured brightness curves of the above-mentioned diffusing screens of which a total of 37 was evaluated. When the screens were classed in three groups, A with a half-angle less than 13°, B with a half-angle between 13° and 30°, and C with a half-angle over 30° (see Fig. 2), it was found that the average values of α for the first and second group were 36% and 5% larger than for the third group.

If the new performance criterion is to be unbiased toward any group, it must then be defined somewhat differently from Eq. (2): (a) the required modification should not affect the second and third groups, or at least to a minor extent only; (b) also it should not change the unity rating for an ideal screen whose brightness is uniform within a certain viewing range $\pm\theta_1$, $|\theta_1| \leqslant 90°$, and zero outside this range; (c) for a screen that satisfies the uniformity requirement (b), but has a finite loss by surface reflection, the criterion should become numerically equal to the relative forward transmission as defined by the righthand side of Eq. (1); and (d) the criterion should be easy to compute from the set of photometric data. The following formula is suggested for the performance figure:

$$\eta = \frac{1}{2}\frac{B_\epsilon(B_0 + B_{10})}{B_0(B_0 + D_0)} \qquad (3)$$

where again,

$$\cos \epsilon = B_0/(B_0 + D_0)$$

B_{10} is the brightness at an angle of 10° to the normal, the other quantities being as defined earlier. The figure η is the product of the quantity α, as per Eq. (2), and the factor 0.5 $(B_0 + B_{10})/B_0$ which lies between the extreme values of 0.5 and 1, depending on the shape of the brightness curve. It is easy to see that the definition (3) satisfies the requirements (b) and (c) because, if B is constant, it reduces to:

$$\eta = B_0/(B_0 + D_0) \qquad (4)$$

which is the relative amount of forward transmission, equal to unity for a hypothetical ideal screen.

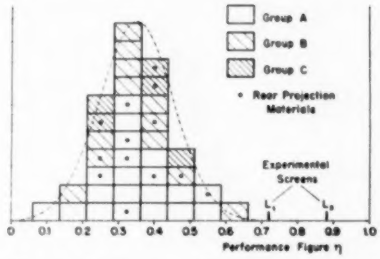

Fig. 3. Frequency distribution of the performance figure η for diffusing screens of random structure.

The goodness of the criterion η with respect to freedom of bias may be judged from the histogram of Fig. 3 in which each member of the three above-described groups A, B and C of diffusers, altogether 37, is plotted as a rectangle over a certain interval $\Delta\eta$ containing its individual η-value. A total of eight intervals has been chosen, covering 60% of the η-range from zero to unity. The dotted curve fitted to the histogram is a tentative frequency curve. It can be seen that all three groups cluster around the same average η of about 0.35, group C somewhat less clearly than the others because of the small number of individuals in this group. There appears to be a tendency of the denser screens to have a larger variance in η, as might naturally be expected.

The small circles indicate those diffusers which are designed and sold as rear-projection screens, while the others are manufactured with other applications in mind. It is surprising to see that there are a number of the latter kind which are equal or superior to screens expressly meant for projection. It is even more surprising that the average rating of the intended screens is not more than 0.36, practically the same as the total average. From the discussion of the fundamental diffusing processes, the figure should be expected to be closer to 0.5. The inevitable conclusion is that the majority of the screens tested represent a step backward from what nature can achieve in random diffusing processes. This disappointing fact has apparently not been pointed out previously.

It has been stressed, however,[2] that substantial improvements can be expected only from applying to projection screens strict optical design principles. On this basis, two experimental rear-projection surfaces with spherical and aspherical lenticulation, respectively, have been designed at the Signal Corps Engineering Laboratories.[6] In Fig. 3 the ratings of these screens are marked at an η-value of 0.72 for the spherical lenticulation and at 0.88 for the aspherical lenticulation.

These evident improvements achieved by deliberate design imply a considerable technical effort. In fact, regardless of screen type, there is no easy way of raising the performance to values near unity, the only exception being ordinary white screens with diffuse reflection of the Lambert type where η, according to Eq. (4), assumes values of about 0.8.

So far the investigation has been restricted to rear-projection screens with negligible absorption, covering the majority of available screens. It remains to be discussed how the performance criterion can be applied to screens in which a moderate amount of absorption is deliberately introduced in order to improve contrast under ambient illumination. The four screens marked by crosses in Fig. 2 are representative of this type. Their ϵ-values lie well below average, indicating relatively low reflection. It appears, however, that some other nonabsorbing diffusers have equally low reflection. In fact, exactly these diffusers are characterized by values of η above average.

An improvement of contrast rendition is obtained only if the absorption introduced attenuates the reflected light to a higher degree than the transmitted light. If the attenuation were the same for both, it might be argued that the screen performance would be essentially unchanged, provided absorption were moderate. The criterion (3) could then be applied without any modification, which would be desirable from the viewpoint of easy computability. There is no doubt that, as the absorption is increased, the apparent performance of the screen would eventually be adversely affected by physiological factors such as decreasing contrast discrimination and decreasing visual acuity. However, the inclusion of such factors in the performance rating could be attempted only on the basis of further specially designed experiments.

As a test of the simplest way which does not consider absorption explicitly, Fig. 4 shows the results for screen 1-S having a neutral absorption of about 29%, in comparison with two nonabsorbing screens 34-B and 18-A (see Fig. 2). All three screens have about the same peak brightness, but the absorbing screen 1-S reflects only half as much light as the ordinary screens. Up to an angle of about 40°, screens 1-S and 18-A have almost identical brightness curves. In the range over 40°, the brightness drop of screen 18-A levels off, while the brightness of the absorbing screen continues to fall. Thus it appears that the better contrast rendition of screen 1-S is achieved at the expense of a lower brightness at viewing angles well over 40° which, however, are not expected to occur in the practical use of screens of this type. The higher rating of screen 1-S, 0.44 vs. 0.33, seems justified, therefore.

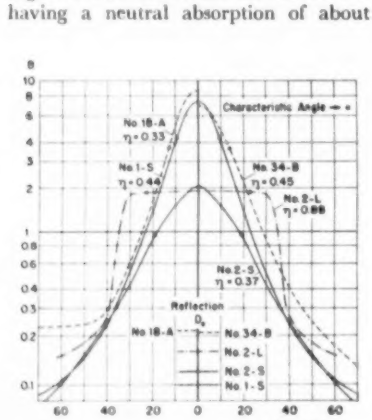

Fig. 4. Comparative performance rating of nonabsorbing and absorbing screens.

On the other hand, screen 34-B, while reflecting more light, drops less steeply in brightness than the absorbing screen. At angles above 20° the disadvantage of higher reflection is almost compensated by a higher forward brightness so that there is very little loss of contrast in this range. At smaller angles the contrast is so good that some loss can easily be tolerated. Since screen 34-B is somewhat better with regard to fall-off, its rating of 0.45 seems again commensurate with the rating of the absorbing screen.

Curve 2-S of Fig. 4 represents another absorbing screen with a higher absorption of about 53% and a reflection which is slightly higher than that of screen 1-S. The relatively great loss of light in this screen is plainly apparent from its downward-shifted brightness curve. Yet, as can be seen from Fig. 2 where this screen is represented by the first cross on the left, the sacrifice of light did not lead to a reduction of the angle ϵ considerably beyond what can be achieved with less or no absorption. The performance figure of this screen is just average, about 0.37, or rather below average in view of the high amount of absorption. It seems that the merit of greatly increased absorption as a means of improving rear-projection screens is dubious, except perhaps in very special applications.

The foregoing examples may raise the question as to what accounts for the usefulness of the criterion η which, admittedly, is based upon selected data pertaining entirely to the central portion of the brightness curve. The corresponding viewing angles cover, in fact, only a small part of the total solid angle into which light is diffused. A partial answer is obtained from considering how the total transmitted light flux is distributed over the viewing range $0<\theta<\pi/2$. The increment dF to the light flux F, per unit screen area, in an infinitesimal solid angle of opening θ is:

$$dF = 2\pi B \cos\theta \sin\theta \, d\theta \qquad (5)$$

or

$$dF = \pi B \sin 2\theta \, d\theta \qquad (6)$$

The increase is highest at that angle θ where the curve B sin 2θ has its maximum. In Fig. 5 this curve is plotted for typical screens belonging to the groups A, B, and C, respectively. On each curve a point P_ϵ is marked at the characteristic angle ϵ associated with that screen. In every case the point P_ϵ lies very close to the maximum, slightly beyond it. As ϵ, according to Eq. (1), forms the basis of the proposed criterion η, it is seen that the latter hinges upon that part of the brightness curve which contributes most of the transmitted flux. Thus η is, in a sense, a most efficient criterion.

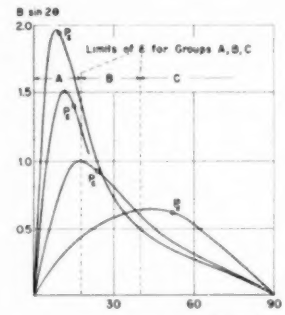

Fig. 5. Relation of characteristic angle ϵ to the flux distribution curve B sin 2θ.

Rating of Reflecting Screens

In view of the different conditions under which rear- and front-projection screens may be used in practice, caution must be exercised in applying to the latter a performance criterion that is well suited for transmitting screens. There are two reasons responsible for the different and more complex situation encountered in reflecting screens. While in transmitting screens the loss D_0 was found to be in a direct relation to the forward peak brightness B_0, a similar relationship does not exist for reflecting screens. In the latter, the loss is caused by the absorption of the screen material. The peak brightness, on the other hand, is in addition largely determined by the surface structure. The second complication lies in the fact that the loss is not directly measurable, but must be calculated from the light-flux balance. If the coefficient of reflection ρ is defined as the ratio of the light flux F reflected per unit area to the light flux incident upon the same area, one obtains according to Eq. (6):

$$\rho = F/\pi = \int_0^{\pi/2} B \sin 2\theta \, d\theta \qquad (7)$$

The incident flux simply equals π, as can be seen by substituting for the screen an ideal diffuse reflector of unit brightness.

In a manner analogous to the pro-

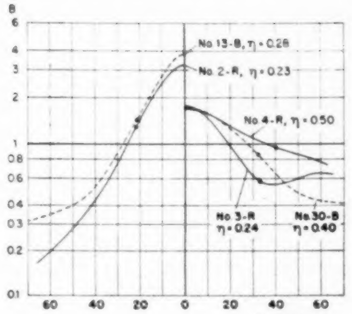

Fig. 6. Performance rating of reflecting screens.

cedure previously followed for transmitting screens, the performance figure for reflecting screens may be defined so that for screens of uniform brightness, within a certain viewing range $\pm\theta_1$, the rating becomes numerically equal to the coefficient of reflection ρ. This would include reflectors of the Lambert type, as an example. In order to secure consistency with the results obtained for rear-projection screens with random diffusion, it may further be required that screens with diffuse specular reflection from randomly arranged particles receive a rating lower than ρ. This can again be done by rating the screens in terms of a certain brightness value B_ϵ, measured at an angle ϵ which is characteristic for the rate of decrease of brightness with increasing viewing angle. By analogy to the previous case, the performance figure can be defined as:

$$\eta = \rho B_\epsilon (B_0 + B_{10})/2B_0^2 \tag{8}$$

This expression satisfies the two foregoing requirements.

Unfortunately, among available reflecting screens of the randomly specular type, there is not sufficient diversity for deriving a relation between the peak brightness B_0 and a characteristic angle ϵ. However, the corresponding relation found for nonabsorbing transmitting screens, curve T of Fig. 2, is likely to fit nonabsorbing reflecting screens after a slight modification. Let the modified curve be denoted by R. In both extreme cases of directional "screens," represented by polished transmitting or reflecting surfaces, the angle ϵ is zero, which means that the curves T and R must merge as ϵ vanishes. In the other extreme case of uniform diffusion, ϵ assumed the value of 60° for transmitting screens, at $B_0 = 0.5$. If, for consistency, the same value of ϵ is required for nonabsorbing diffuse reflectors of unit brightness, the point O of curve T must be shifted from $B_0 = 0.5$ to the location O′ on curve R, at $B_0 = 1$. It appears that R is practically straight and represented by:

$$\epsilon = 60/B_0^{0.63} \text{ (degrees)} \tag{9}$$

Since the relation (9) is valid for ideal reflectors, the logical way of computing ϵ for absorbing reflectors is to substitute in Eq. (9) for the peak brightness that value which the particular screen would have if it were nonabsorbing. This value can be assumed to be B_0/ρ.

An example may illustrate the procedure. Curve 2-R on the lefthand side of Fig. 6 represents an aluminized stereo projection screen* with $B_0 = 3.24$. By application of Eq. (7), ρ is found to be 0.64. The corresponding peak brightness for zero absorption therefore equals 5.07. Hence from Eq. (9):

$$\epsilon = 60/5.07^{0.63} = 21.6°$$

From curve 2-R one reads at this angle a brightness B_ϵ of 1.31 so that, from Eq. (8), η is finally obtained as 0.23. Curve 13-B pertains to a rear-projection screen of very similar characteristic, with $\epsilon = 21.1°$ and a rating of 0.28. A comparison of the two graphs proves the rating to be as just as can be expected, the latter screen deserving a slightly higher figure.

The case of a typical beaded screen, shown by curve 3-R† on the righthand side of Fig. 6, is complicated by its anomalous brightness curve which has a dip in the vicinity of 40°. Since the characteristic value B_ϵ just happens to lie in this dip, it seems more appropriate in this case to substitute for B_ϵ the brightness value of the adjacent secondary maximum. This leads to the value η of 0.24. For comparison, curve 30-B represents a transmitting screen of the same peak brightness and the same forward flux, but with a slower fall-off which results in a higher rating of 0.40. Curve 4-R shows a recently developed lenticulated screen‡ of high reflection and moderate fall-off, receiving a rating of 0.50.

The last example reflects the improvement obtained by relying on deliberate design rather than on random processes. Considerably higher performance figures are possible and within practical reach, as is shown by curve 2-L of Fig. 4 and by an experimental reflecting screen[2] with wide horizontal and narrow vertical spread, having a mean rating of about 0.8. Beside giving an unbiased rating of conventional screens, the proposed criterion should also be useful for appraising future screen improvements.

APPENDIX

Reflection at a Refracting Boundary With Random Surface Structure

The diffusing surface is illuminated by a directed beam of perpendicular incidence. The brightness B of a surface element viewed at an angle θ to the normal is assumed to follow the bell-shaped curve:

$$B = B_0/(1 + a^2\theta^2) \tag{10}$$

where B_0 is the brightness at $\theta = 0$, and a, the reciprocal of the half-angle θ_h at which the brightness drops to half of B_0. A curve of this shape is a good approximation to actual conditions, in general better than Hill's cosine-power curves because diffusers still have a finite brightness at 90°. Equation (10) is also a better approximation than a Gaussian normal curve of error which declines faster than the brightness curve of practical diffusers.[3]

The light flux radiated per unit area into an infinitesimal solid angle $d\omega$ is:

$$dF = B \cos \theta d\omega \tag{11}$$

Restricting for a moment the consideration to small values of θ, one can write:

$$d\omega = 2\pi\theta d\theta \tag{12}$$

$$dF = 2\pi B_0 \frac{\theta d\theta}{1 + a^2\theta^2} \tag{13}$$

The incident light beam which passes through a small surface element of slope angle σ is deflected according to the law of refraction. If the other surface of the diffusing screen is smooth, the angle of deflection, θ, for small angles σ, is given by:

$$\theta = (n - 1)\sigma \tag{14}$$

n denoting the refractive index of the screen material.

Substituting into Eq. (13):

$$dF = \text{const} \frac{\sigma d\sigma}{1 + a^2(n - 1)^2\sigma^2} \tag{15}$$

Equation (15) can be interpreted as stating that in order to produce the brightness distribution according to Eq. (10), surface elements of slope σ must occur per unit area with a relative frequency or probability $\phi(\sigma)$ of:

$$\sigma/[1 + a^2(n - 1)^2\sigma^2]$$

In other words, a relative portion $\phi(\sigma)$ of the diffusing surface must be covered by refracting elements whose slope lies between σ and $\sigma + d\sigma$ in order to transmit the flux:

$$dF = \text{const } \phi(\sigma)d\sigma \tag{16}$$

The above expression for $\phi(\sigma)$ was derived for small angles σ and thus requires a correction for larger angles up to 90°. Elements transmit less and less light as their slope angle increases because their projected area, perpendicular to the incident beam, becomes smaller. This is taken into account by multiplying the expression for $\phi(\sigma)$ by $\cos \sigma$. Thus, as a first approximation:

$$\phi(\sigma) = A\sigma \cos \sigma/(1 + k^2\sigma^2) \tag{17}$$

$$k = (n - 1)a \tag{18}$$

In order to obtain the probability one for the occurrence of any transmission in the

---

* Data taken from Fig. 6 of Reference 2.
† Data taken from Fig. 7 of Reference 2.
‡ Data taken from Reference 7

range $0 < \sigma < \pi/2$, the parameter A is now fixed according to:

$$1/A = \int_0^{\pi/2} \frac{\sigma \cos \sigma}{1 + k^2\sigma^2}\, d\sigma \qquad (19)$$

On the above assumptions the question will now be studied as to the amount of light reflected straight backward if the surface elements are considered as partial reflectors. For simplicity the coefficient of reflection will be assumed as independent of the angle of incidence, which is, of course, not exact. Any refinement in this regard is, however, not warranted because the entire analysis is only an approximation intended to show a general trend.

Unless attributable to backward scattering, the main part of the light flux reflected from larger surface elements has its origin in multiple reflection. Single reflection must be discounted because it could not explain the nearly uniform brightness distribution of the reflected light. If reflected only once, the light should have a distribution of the type of Eq. (10), but with a much steeper peak. As can be seen from Eq. (15), by substituting $n = -1$ for reflection, the half-angle of the brightness distribution would become only one-quarter of that for transmission. Moreover, in the case of single reflection, the light that is reflected in the direction of the surface normal should not become partly depolarized if the incident light was polarized. This again is contrary to experimental evidence. Therefore the hypothesis may be tried that the reflected flux is due to double reflections as shown in Fig. 7. This requires the two reflecting elements S and S' of opposite azimuths to have slope angles such that:

$$\sigma + \sigma' = \pi/2 \qquad (20)$$

The two reflections, taken separately, occur with the respective probabilities $\phi(\sigma)$ and $\phi(\sigma')$. Thus for double reflection the probability is proportional to:

$$\phi(\sigma)\cdot\phi(\sigma') = A^2 \frac{\sigma\left(\frac{\pi}{2} - \sigma\right) \sin \sigma \cos \sigma}{(1 + k^2\sigma^2)\left[1 + k^2\left(\frac{\pi}{2} - \sigma\right)^2\right]} \qquad (21)$$

Since σ may lie anywhere between zero and $\pi/2$, the total straight backward reflection D_0 is obtained by integrating between these limits.

$$D_0 = \text{const} \int_0^{\pi/2} \phi(\sigma)\phi(\sigma')d\sigma \qquad (22)$$

This result can be expressed in the final form:

$$D_0 = cA^2N \qquad (23)$$

$$N = \int_0^{\pi/2} \frac{\left(\frac{\pi^2}{4} - t^2\right)\cos t\, dt}{\left[4 + k^2\left(\frac{\pi}{2}+t\right)^2\right]\left[4 + k^2\left(\frac{\pi}{2}-t\right)^2\right]} \qquad (24)$$

The quantities ϵ and α which have been defined in the text can now be computed as follows. If F is again the light flux radiated per unit area, the apparent brightness in the forward direction, $\theta = 0$, is found from Eqs. (12), (14), (16) and (17).

$$B_0 = \left(\frac{dF}{d\omega}\right)_{\theta=0} = \text{const}\left[\phi(\sigma)\frac{d\sigma}{d\omega}\right]_{\sigma=0} = \text{const}\,\frac{A}{2\pi(n-1)^2} = \frac{A}{b} \qquad (25)$$

Therefore,

$$\cos \epsilon = \frac{B_0}{B_0 + D_0} = \frac{1}{1 + \frac{bD_0}{A}} = \frac{1}{1 + bcAN} \qquad (26)$$

In diffusers of the type considered, the reflected brightness is small in comparison to the transmitted brightness so that as approximation from Eq. (26):

$$\epsilon^2 = 2bc\,AN \qquad (27)$$

Substituting into Eq. (10) and writing C for the constant bc, one finds:

$$B_\epsilon/B_0 = 1/(1 + 2Ca^2\,AN)$$

Therefore,

$$\alpha = (B_\epsilon/B_0)\cdot\cos\epsilon = [(1 + 2Ca^2AN)\,(1 + CAN)]^{-1} \qquad (28)$$

Table I

a	4	10	30
s	23.0	139	1250
θ_h (degrees)	14.32	5.73	1.91
A	5.12	15.91	84.1
N	$1.122 \cdot 10^{-2}$	$0.623 \cdot 10^{-3}$	$1.036 \cdot 10^{-5}$
ϵ (degrees)	13.66	5.74	1.70
α	0.500	0.499	0.560

Table I gives the results of a numerical evaluation for three different parameters a covering a very wide range of screen characteristics. This is evidenced by the wide spread of the corresponding shape factor s.[1] The latter has been so determined as to furnish a brightness curve

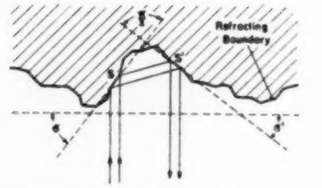

Fig. 7. Double reflection at an irregular refracting boundary.

with the same half-angle θ_h as that according to Eq. (10). The quantities A and N are computed from Eqs. (19) and (24), respectively, with a refractive index n of 1.5. Since the foregoing analysis leaves the constant C open, its value has been chosen so that the value of α in the column $a = 4$ is just $\frac{1}{2}$, which is in the range of actual experimental results. The important point to be shown is the small variation of the other two figures for α, despite the extremely wide variation of the brightness curves. It should be noted, for instance, that the quantities A which are approximately representative of the peak brightness vary in a ratio 1:16. The slight upward trend of the values α with decreasing half-angle θ_h is confirmed by experiments. The resulting angles ϵ are also very well consistent with experimental data.[5]

Acknowledgment

The author wishes to thank Messrs. D. Sacher and R. Snyder of the Photographic Branch, Squier Signal Laboratory, for their assistance in taking and evaluating numerous photometric measurements.

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Duration and Peak Candlepower of Some Electronic Flashlamps

By HAROLD E. EDGERTON, ROBERT BONAZOLI and JOHN T. LAMB

It is pointed out that the trend of modern electronic flash equipment is toward longer flash duration. After proposing a method of defining duration, an approximate method of calculating duration is given, together with resistance constants of commonly available flashtubes. Some information is given regarding the production of short flashes of light in the microsecond and submicrosecond range.

THE OBJECT of this paper is to consider the factors that affect the instantaneous light output of some commonly used flashtubes, so that flash duration can be predicted.

Electronic flash equipment design has been trending toward lower voltages and larger capacitors of the electrolytic type. As a result, the flash duration has become so long that the electronic-flash system is no longer considered to be high speed for some types of photography. For example, the wings of birds in flight show appreciable blur when photographed with 900-v, 100-wsec flash equipment. With modern 450-v units, the blur becomes still more pronounced, in fact, violently objectionable for many subjects such as birds.

There have always been some people who purposely want blur to suggest motion in a still photograph. Low-voltage electronic-flash equipment will do this. Other people prefer crystal-sharp negatives without blur and consider any blur in a negative, no matter how small, to be a thing to avoid at all times.

Allowable Flash Duration

Whether or not the duration of a particular flash unit will give a blurred photograph depends upon the resolution and the velocity of the object that is being photographed.

The required exposure time for stopping motion can be estimated as indicated by the following example. Consider a golf ball in flight immediately after it has left a golf club at a velocity of 100 ft/sec. Suppose that a close-up photograph is to be made where 0.01 in. can be resolved on the final enlarged photograph of the golf ball. Now calculate the time required for the ball to travel this 0.01 in.

$$\text{time of travel} = \frac{\text{allowable distance}}{\text{velocity of object}} = \frac{0.01\text{ in.}}{1200\text{ in./sec}}$$

$$= \frac{1}{120{,}000}\text{ sec, or } 8.3\ \mu\text{sec}$$

The flash duration of most commercial flash units is much longer than this. In fact, the duration of modern 100 wsec, 900-v equipment, using the General Electric FT-110 flashtube, is about 1/3000 sec (330 μsec). The golf ball travels about $\frac{1}{2}$ in. in 1/3000 sec, producing a badly blurred photograph.

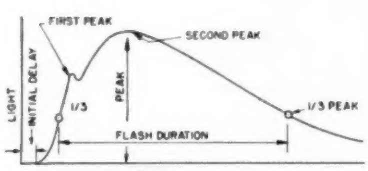

Fig. 1. A sketch to illustrate a proposed method of defining "duration" of a flash of light from an electronic flashtube.

Presented on May 6, 1954, at the Society's Convention at Washington, D.C., by Harold E. Edgerton, Robert Bonazoli (now on duty with the Signal Corps) and John T. Lamb (who read the paper), Massachusetts Institute of Technology, Cambridge 39, Mass.
(This paper was received on March 5, 1954.)

Suggested Definition of Duration

There is no standard definition of duration in electronic-flash terminology at present. The best way to describe duration is to show a complete plot of the light as a function of time, as in Fig. 1. Thus the entire story of the initial delay, the build-up of light, the irregularities, the peaks and the decay can be graphically described. However, one is usually interested in a round number for duration so he can estimate the blur that he will encounter for a specific example. We have defined "duration" as the time between the $\frac{1}{3}$ peak-light points on the rising and falling portions of the light curves as illustrated in the accompanying light-time curve, Fig. 1.

The $\frac{1}{3}$ peak values are selected since they are easily located on an oscillogram. Also, the area under the light curve, in candlepower seconds, is roughly the product of the peak light in candlepower by the duration as determined by the $\frac{1}{3}$ peak points, as just described. The photographic duration may be several times longer due to the long tail of light, the nature of the subject and the exposure. As a rough criterion, double the $\frac{1}{3}$ peak duration (the duration between $\frac{1}{10}$ peak-light point) could be used for photographic computations.

Factors Influencing Duration

The light from an electronic flashtube depends upon several factors such as:

1. Type of flashtube;
2. Size and type of capacitor;
3. Initial voltage to which the capacitor is charged; and
4. Series inductance and resistance in the discharge circuit.

It has been found that most flashtubes can be assigned an approximate resistance value for most of the fully loaded conditions. This tube "resistance" (R) can be defined as the ratio of the initial condenser voltage divided by the peak current, when a capacitor greater than some nominal value is used. The peak current is almost independent of the size of the capacitor if the capacitor is larger than this nominal value. The actual volt-ampere characteristic of a flashtube is an involved nonlinear function, since the tube is a gas-discharge device. Figure 2 illustrates the time variation of the voltage and current in a flashtube.

A short flashtube of large cross-sectional area will have a low resistance and will discharge a capacitor at a fast rate with a short duration. Also, a small capacitor will discharge more quickly than a larger one.

From linear transient theory, the time constant of the *voltage* discharge of a capacitor into a resistor is RC seconds. At this value of time, the capacitor voltage has decreased to $1/e = (0.37)$ of the initial value, where e is the base

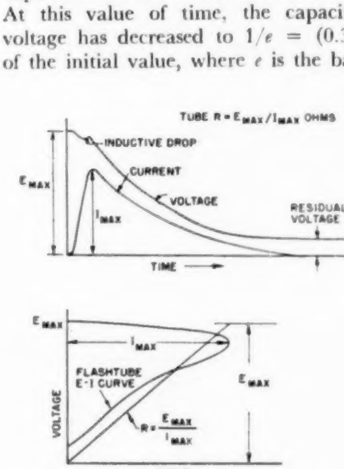

Fig. 2. Above, typical curves of flashtube voltage and current as a function of time. Below, same data plotted as volt-ampere curve of flashtube.

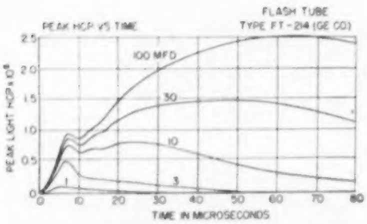

Fig. 3. Instantaneous horizontal candlepower as a function of time for different capacitors at 2000 v, FT-214.

of natural logarithm — 2.7183. Since the power of the discharge is roughly proportional to the square of the voltage, the time constant for the power or light is $T = RC/2$.

Even with the nonlinear flashtubes, the duration can be estimated by using the above relationship, but keeping in mind the limitations regarding flashtube resistance. Thus:

$$\text{flash duration} = RC/2 \text{ sec (approx.)}$$

Table I gives flashtube resistances for use in the above equation. Under full load conditions (rated voltage and capacity) the measured duration of most tubes is from 10% to 30% longer than $\frac{1}{2}$ RC. This error increases for higher voltages and lower capacities, and the duration may become longer than RC.

An increase of the voltage on the capacitor in general causes a small decrease in the tube resistance, thus decreasing slightly the flash duration. More important, if the energy per flash is held constant as voltage is increased, the capacitance decreases inversely as the square of the voltage. Therefore, doubling the voltage will reduce the capacitance to $\frac{1}{4}$ of its initial value, and will reduce the duration roughly by the same amount, $\frac{1}{4}$.

The series circuit inductance and resistance also influence the discharge time. As long as the tube resistance is sufficiently large to predominate in the circuit, the series inductance only appreciably influences the first part of the discharge, preventing the rapid build-up of current within the tube. For efficient operation, the circuit resistance should always be much smaller than the tube resistance.

Table I. Flashtube resistances as measured on sample flashtubes of several types.

Flashtube type	E_{max}, volts	Capacity, μf	I_{max}, amp	R, ohms
FT-214	2000	1	150	13.2
	2000	2	220	9.1
	2000	10	300	6.7
	2000	30	340	5.9
	2000	100	410	4.9
	1500	100	225	6.7
	1000	100	100	10.0
FT-218	1000	5	254	3.9
	1000	10	363	2.75
	1000	30	473	2.1
	1000	100	527	1.9
FT-110	1000	100	618	1.6
FT-118	1000	100	582	1.7
	500	100	218	4.6
FX-1	2000	1	236	8.7
	2000	3	455	4.4
	2000	10	728	2.7
	2000	30	840	2.4
	2000	100	1020	2.0
	1500	100	636	2.4
	1000	100	355	2.8

Table II. Four FT-214 flashtubes show the following variability when loaded with 100 μf at 2000 v.

Tube No.	Peak current, amp	R, ohms	Peak, h-cp	Light output, h-cp-sec	Duration, μsec
A	400	5	2.5×10^6	665	280
B	375	5.3	2.5×10^6	676	290
C	410	4.85	2.6×10^6	706	260
D	400	5	2.6×10^6	665	280

Duration Characteristics — FT-214, FT-210, FT-220

These three General Electric flashtubes use the same Pyrex, $4\frac{1}{2}$-turn spiral flash element wound from 6-mm OD tubing of about 10 in. in length. Xenon gas is used at about $\frac{1}{5}$ atmospheric pressure. A series of light-time traces are given for this tube as a function of capacity in Fig. 3. The duration, as measured between the $\frac{1}{3}$ peak values, has also been plotted as a function of capacity and voltage in Fig. 4. Likewise, a plot of the peak horizontal candlepower against the same quantities is

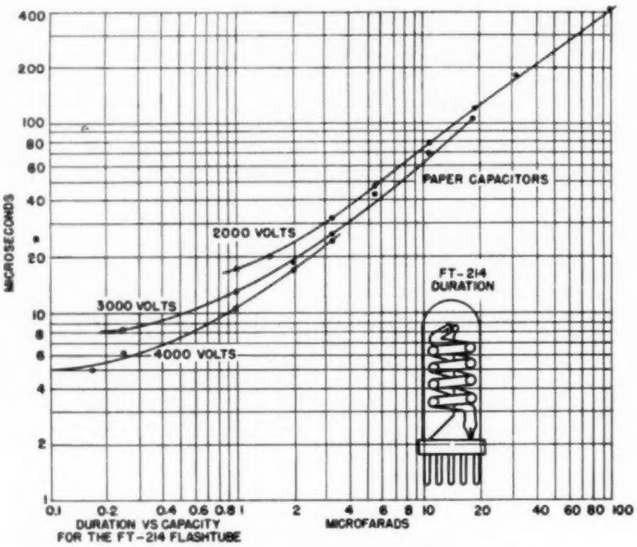

Fig. 4. Flash duration as a function of capacity and voltage.

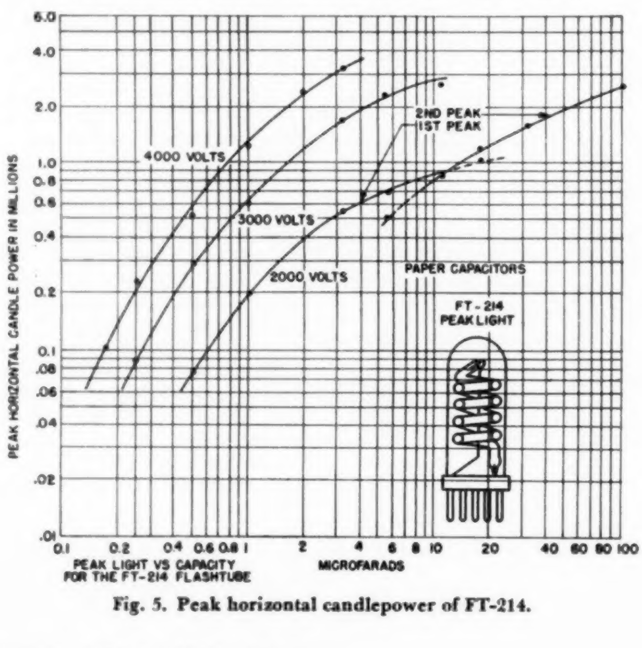

Fig. 5. Peak horizontal candlepower of FT-214.

also given, as measured with an S-4 phototube surface, in Fig. 5.

The glass walls of this flashtube will craze if loaded much over the approximate full load of 100 μf at 2000 v, that is, 200 wsec.

Our experiments for four FT-214 flashtubes show, in Table II, the following variability when loaded with 100 μf at 2000 v.

Note that flash duration calculated by the approximate equation RC/2 shows an error of about 10% on the short side. The variation from tube to tube is caused by manufacturing tolerance and age. Straight flashtubes, such as the FX-1, show less variation since the dimensions are held more closely than in a spiral.

Duration Characteristics of FT-110 and FT-218

These flashtubes are nominally rated as follows:

	Voltage	*Energy*	*Duration*
FT-110	900 v	100 wsec	330 μsec
FT-218	900 v	200 wsec	600 μsec

A shorter flash can be obtained by operating at a higher voltage. For example, observe the flash duration data in Fig. 6, the curve sheet of the FT-110 as a function of capacity and voltage. Most FT-110 flashtubes will self-flash at 2500 v. The curve marked 3500 v was for a "hard starter." The light was measured in a preferred direction, where the h-cp (horizontal candlepower)

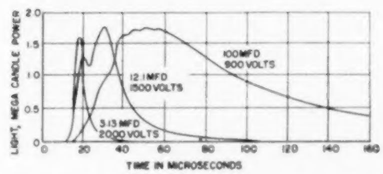

Fig. 8. Instantaneous horizontal candlepower as a function of time.

output was a maximum. Thus for the FT-110, the direction of measurement was perpendicular to the plane containing the two legs of the lamp. A study of the h-cp output as a function of angle showed that the horizontal candlepower diminished to 56% of maximum when viewed in a direction where the two legs were in line. At this angle, the light from the far leg is eclipsed by the nearer one.

Three curves of about the same peak-light output, but of different duration, are shown in Fig. 8, for the FT-110 flashtube. Note that the duration and peak light check roughly from the information of Figs. 6 and 7.

The internal resistance and inductance of the electrolytic capacitor become more important when the capacitors are connected in series, since the combined impedance may be appreciable, compared to the resistance of the flashtube.

Experimentally, it is found that the peak-light output will be greater with a paper capacitor than with an electrolytic of the same rating. Also, crazing of the flashtube may occur with paper capacitors while it may not with electrolytics of the same total rating. There are variations among electrolytic capacitors due to construction modifications.

Below are described various flash units of different flash durations of 100 μsec and shorter.

A 100-μsec-Duration Flash Unit

A flash unit,[1] that has been found useful for bird photography was designed using the technical information in this article. The circuit is given in Fig. 9. Both the FT-110 and the FT-218 can be used in this circuit. The output and duration of each is given below. The flash capacitor consists of four 280 μf electrolytic capacitors in series.

	C	*V*	*Duration, μsec*
FT-110	70	1800	92
FT-218	70	1800	100

A 10-μsec-Duration Flash Unit

A flash unit of about 10-μsec duration can be made using the identical circuit of Fig. 9, except the four series capacitors are replaced by a single 2-μf paper capacitor. Notice that the bleeder string of resistors must still be connected across the high-voltage terminals to supply voltage to the thyratron trigger circuit.

The light output can be estimated by multiplying the duration from Fig. 6 and

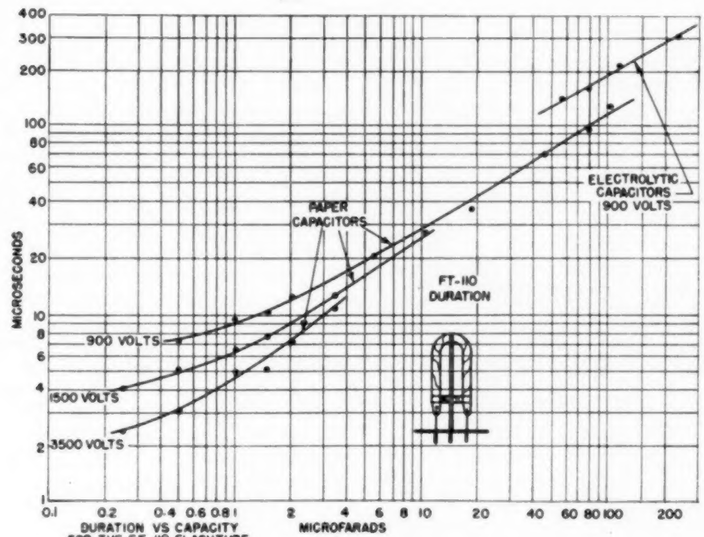

Fig. 6. Flash duration of the FT-110.

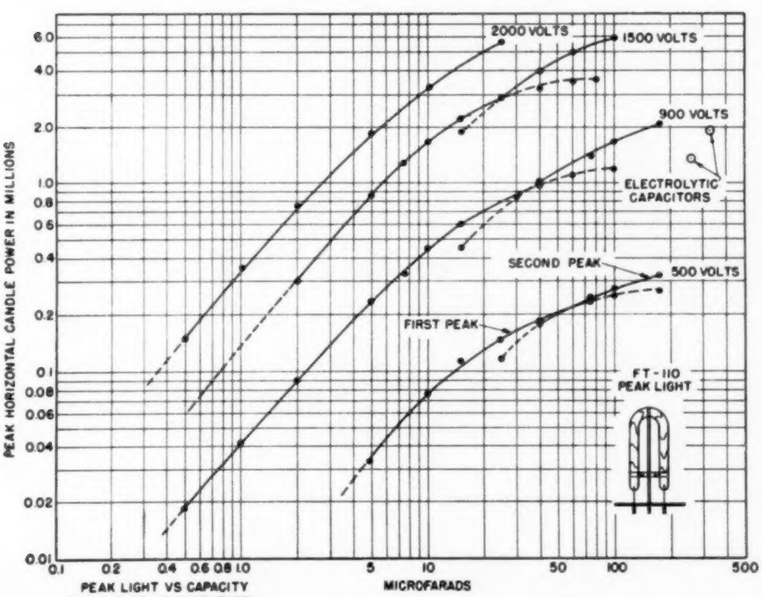

Fig. 7. Peak horizontal candlepower of FT-110.

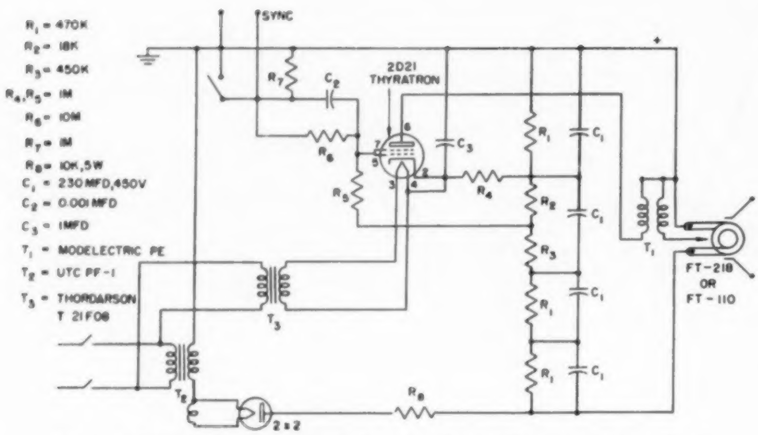

Fig. 9. Wiring diagram of a typical flash unit for 100 μsec flash duration.

the peak light from Fig. 7, as shown below.

Approx. output = 8 μsec $\times$ 0.8 $\times$ 10^6 cp = 6.4 (h-cp-sec)

The guide factor can be computed from the following:[2]

$$DA = \sqrt{\frac{S}{C}\,(\text{h-cp-sec})M}$$

where

M = reflector factor = 10;
S = ASA film exposure index for black-and-white film = 100;
C = a constant = 15 to 30;
D = distance in feet;
A = lens aperture; and
h-cp-sec = lamp output in horizontal candlepower seconds.

Substituting numbers:
DA = 20 aperture $\times$ feet (guide factor)

Thus the flashlamp in a reflector should give an adequate exposure on fast black-and-white film at 5 ft from the subject at $f/4$.

1-μsec-Duration Flash Unit

To achieve a 1-μsec flash duration, special flashtubes, special low-inductance capacitors and wiring, and high voltages must be used. It is observed that the quantity of light rapidly becomes smaller as the flash duration is made shorter.

The successful photography of bullets without blur requires a flash of about 1 μsec duration. For example, a 0.30 caliber bullet, traveling at 2700 ft/sec, travels a distance of 0.032 in. in 1μsec. Usually there is some shiny spot on a bullet which gives a highlight, caused by the dim afterglow of light from the flashtube. Such a photograph will show streaks in the direction of travel of the bullet.

The General Radio Microflash (Type 1530) has a short ($1\frac{1}{2}$-in.) argon- and hydrogen-filled flashtube, which is flashed from a 0.33-μf capacitor charged to 7000 v. The wiring inductance is made a minimum by placing the capacitor in the lamphouse. The effective duration of the flash is about 2 μsec. A guide factor of about 20 (aperture $\times$ feet) is possible with fast black-and-white film.

A spark-gap source operated from a 0.12-μf capacitor of low inductance, charged to 5000 v, is described by Kovásznay.[3] The duration is stated to be 0.8 μsec to $\frac{1}{30}$ of peak light.

H. F. Quinn and his co-workers[4] describe a short-flash source using xenon flashtubes with a controlled three-electrode spark gap.

Units With 0.1 μsec or Less Duration

A few experimenters have reported very short flash durations, especially with low energy, a small air gap, and very low circuit inductance. For example, J. A. Hornbeck[5] shows a 0.1-μsec flash unit with 0.001 μf. J. W. Beams and his co-workers[6] use a spark gap in series with a resistor and a transmission line, the latter serving as an energy-storage element. The resistor is the characteristic impedance (52 ohms) of the transmission line. The duration of the spark is about 0.1 μsec, which corresponds to the reflected time of the first wave through the line. A double flash unit with $\frac{1}{5}$-μsec flashes, shown by Edgerton[7], uses 0.005 μf at 7000 v for the first spark and 0.01 μf for the second.

Since the output of these feeble sparks is so very small, the light is usually arranged for silhouette photography.

Numerous references to short-flash sources involving spark gaps, exploding wires, and tubes can be found in two bibliographies published in the *Journal*.[8]

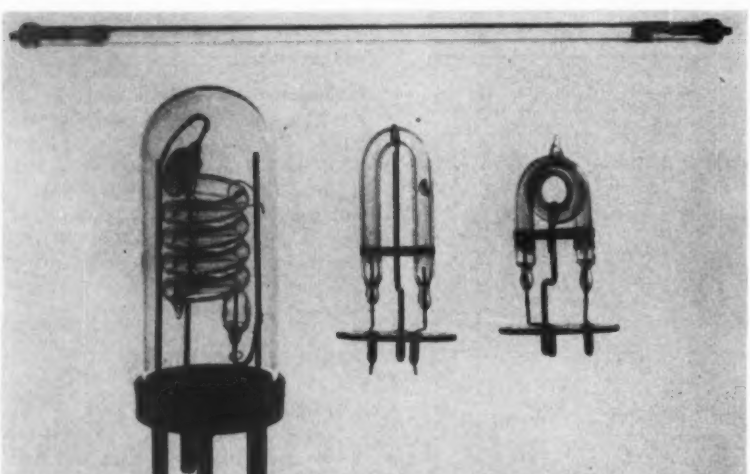

Fig. 10. Photographs of electronic flashtubes whose characteristics are given in this paper: top tube, FX-1, 20 cm xenon; large spiral, FT-214, General Electric Co.; V-shaped tube, FT-210, General Electric Co.; and $1\frac{1}{2}$-turn spiral FT-218, General Electric Co.

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Production Studio Multiple-Stage Design

By DANIEL J. BLOOMBERG, JOHN E. POND and MICHAEL RETTINGER

The paper discusses a new multiple, sound stage design which increases production efficiency by providing both centralized facilities and an acoustic isolation, permitting set construction and preparation on one or more stages while producing on an adjacent stage. The methods of obtaining the acoustic isolation are described, together with other novel features.

Republic Studios recently completed the construction of a multiple stage, Figs. 1 and 2, consisting of four sound stages, each 60 × 100 ft, a hairdressing and make-up department and 12 dressing rooms and rest rooms, all located under a common roof. In planning this building attention was primarily directed toward efficient production operation by providing integrated facilities in a central location (see Fig. 3). Emphasis was placed on the requirement that set construction and preparation could be carried on in one or more stages while normal production continued in an adjacent stage. The adoption of an individual stage 60 × 100 ft was not the result of a haphazard guess, but rather the selection after a careful study of operations on small and medium-sized stages.

In establishing the stage wall design, noise level measurements were made at the proposed site. This survey disclosed maximum noise levels in the order of 75 db. For normal dialogue recording, the ambient noise level on a sound stage should be 30 db or lower. Thus the exterior wall insulation against airborne noise was determined as a minimum of 45 db. On the other hand, the maximum noise levels resulting from normal stage activities are more nearly in the order of 85 db. Therefore, the average transmission loss of the walls between the stages was specified as a minimum of 55 db.

The stages are equipped with an air-circulation system which has two operating cycles; one for high-speed evacuation of gases, having a complete air-change cycle in 5 min and a low-speed control which provides a complete air change in 10 min. These controls can be worked automatically from the remote switchboard or manually by the sound mixer on the set. The fresh air is drawn from a plenum chamber under the stage flooring through acoustic air traps into the stage proper.

The sound-stage floor design was given particular study to derive a floor that would be noiseless and maintain proper rigidity under peak stage load conditions. The design specifications required a floor carrying capacity of 500 psf with a deflection not greater than 0.09 in. (5/64) under uniform load. The floor supports consist of concrete columns 5 ft on center, 6 × 12 in. structural girders 5 ft apart and 2 × 8 in. joists 12 in. on center. The floor is constructed of 1 × 6 in. diagonal subfloor rough sanded, and 1 × 4 in. tongue-and-groove, vertical-grain, pine-finish floor. The subfloor and finish floor are both nailed through to the joists with No. 10 coated nails by a pneumatic nailer to insure a tight fit and even penetration.

One of the novel features contained in this structure is a newly designed pedestrian door which is an acoustic safety door with panic latches (see Fig. 4). This door has been adopted as a standard throughout the studio and consists of two partitions constructed in the following manner.

The first partition or inner door section is comprised of two sheets of $\frac{3}{4}$-in. exterior grade plywood laminated with a solid sheet of $\frac{1}{16}$-in. lead. This

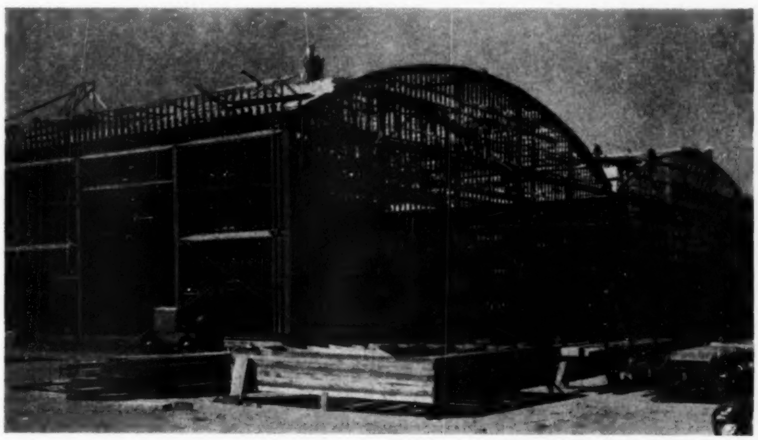


Fig. 1. Multiple stage in the process of construction at Republic Studios.

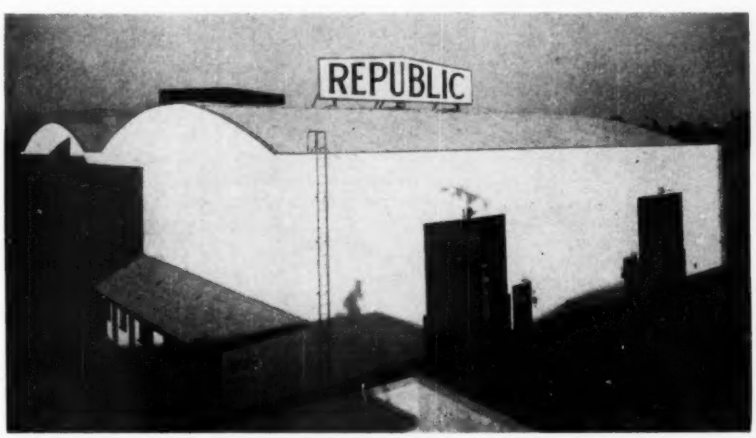


Fig. 2. Completed building housing the multiple stage.

Presented on May 5, 1954, at the Society's Convention at Washington, D.C., by John E. Volkmann for the authors Daniel J. Bloomberg and John E. Pond, Republic Productions Inc., 4024 Radford Ave., N. Hollywood, Calif., and Michael Rettinger, Radio Corporation of America, RCA Victor Div., 1560 N. Vine St., Hollywood 28.
(This paper was received on December 7, 1953.)

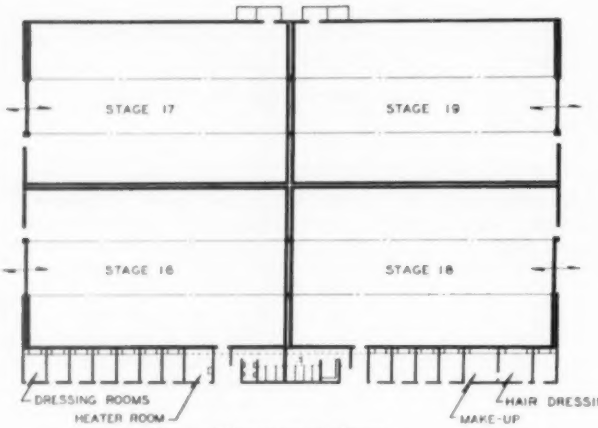


Fig. 3. Plan view of stages.

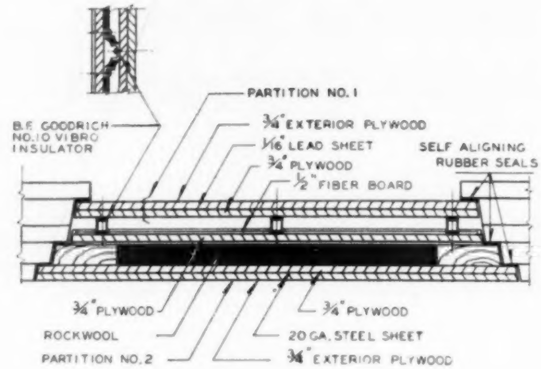


Fig. 4. Horizontal cross section of the stage acoustic safety door.

unit is mounted on the inner face of the second partition with rubber vibro insulators providing a 1½-in. air space between the door segments. The second partition is constructed of a layer of 1-in. plywood facing the air space, 4 in. of rockwool and two additional ¾-inch plywood sheets separated by a membrane of 20-gauge steel. The first partition section contacts one complete rubber seal on the door frame and the second partition contacts the door frame in two steps through rubber seals. Thus, the two door partitions make three complete seals with the door frame. When the door is closed, the first partition, being mounted on rubber vibro insulators, is in mechanical shear, thus effectively filtering vibrations transmitted from the first section to the second. The three points of contact are actually forced into self-aligning rubber seals, thereby preventing air-borne sound leakage. Actual acoustic measurements made with a General Radio Sound Level Meter indicates a sound transmission loss of 45 db at 1000 cycles.

Another novel feature is the equipment stage door which runs on a railroad steel track with manual operation through a chain-link reduction drive and an automatic seal (Fig. 5). The automatic self-sealing device consists of a plunger mounted in the face of the door which is depressed by a doorstop in the last inch of closing, actuating a lever system which lowers the bottom door seal against the cement threshold. These stage doors weigh approximately 3½ tons each and can be opened or closed with ease by one person.

In the early days of sound recording, comparatively little was known about providing economic yet adequate sound insulation of sound stages. Thus, in one case a stage was constructed which consisted of two 1-ft thick concrete walls, separated from each other by a 2-ft air space. The cost of the building was very high and the time of construction relatively long. This particular stage was excessively insulated, since a single concrete wall 1-ft thick would have been more than sufficient to provide an acceptable noise level in the interior. On the other hand, some sound stages were constructed which embodied so little sound insulation that additional construction was required subsequently, which resulted in increased building cost. Today, sound stages can be constructed on principles developed by thorough studies.

In general, three factors contribute toward noise in the studio: (1) the transmission of air-borne sounds through such openings as doors, ventilators, cable openings, etc.; (2) the transmission of solid-borne vibrations, such as a hammering, tamping, etc.; and (3) by the direct transmission through various components of the building which act as diaphragms put into motion by the air-borne vibrations striking them.

It is also well known that in the case of homogeneous walls of various types, the sound insulation is determined chiefly by the mass of the wall per unit area. The manner in which the edges of the material are fastened to the structural surroundings is generally less important than the weight of the wall per unit area. This is certainly so in the case of large panels, although for smaller sections, some deviations may prevail. It is also frequently thought that in the case of homogeneous single section walls, certain types of material are endowed with special sound insulation qualities. Thus, the use of sheet lead, fiberboard or cork

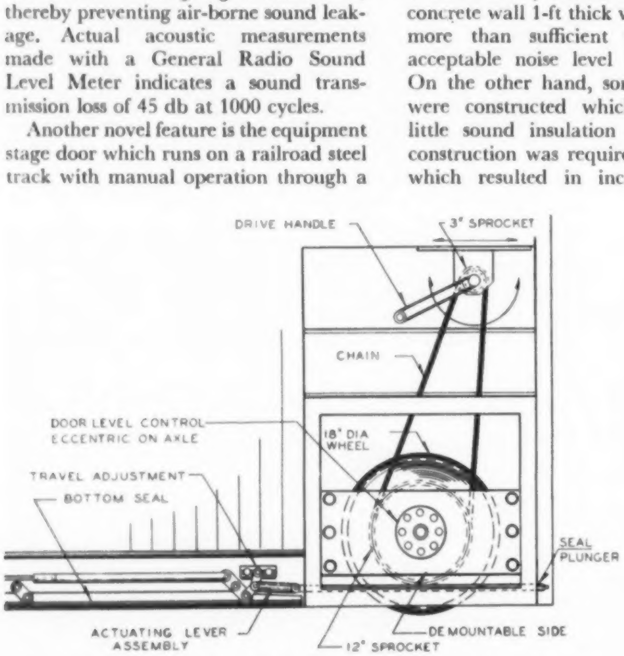


Fig. 5. Equipment door chain-drive and bottom-seal mechanism.

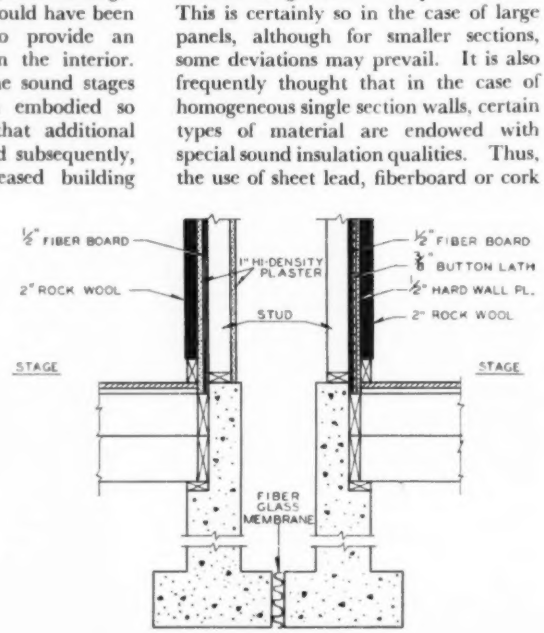


Fig. 6. Interior wall section.

board is often recommended as being especially helpful in preventing the transmission of sound through them. But this is a fallacy. A cork board, of such thickness as to weigh as much as a sheet of lead of given thickness, has much the same sound transmissive properties, except perhaps at the frequency where resonance occurs.

Another popular misconception is that heavy walls are effective as sound insulators. It is true that sound insulation can be increased by making a homogeneous wall thicker, but the increase in sound transmission loss is relatively small when the wall thickness is doubled. Thus, a 12-in. thick concrete wall has a transmission loss* only 6 db greater than a 6-in. thick concrete wall. If, however, a concrete wall were made of two 6-in. thick partitions which are structurally isolated from each other, then the transmission loss would be double that of a single 6-in. concrete wall. This property of sound insulation is so noteworthy that it may well be repeated in slightly different words; thus, doubling the thickness of a homogeneous wall increases the transmission loss by less than 6 db, whereas when two homogeneous walls are structurally isolated from each other, the transmission losses of the two walls may be added arithmetically. To cite a specific example, let us assume that a single homogeneous wall has a transmission loss of 30 db. Making this wall twice as thick increases the transmission loss to 35 db. If two walls (Fig. 6) are built which are structurally isolated from each other, each wall having a transmission loss of 30 db, then the combined transmission loss of the two walls is 60 db.

The transmission loss ($T.L.$) of an elastically restrained nonporous partition is given by:

$$T.L. = 10 \log_{10} \left(\frac{(r + 2R)^2}{4R^2} + \frac{\pi^2 f^2 m^2 [1 - (F_0/F)^2]^2}{R^2} \right)$$

where

r = internal dissipative resistance of partition,
R = specific acoustic resistance of air,
= 41.5 (g/sq cm/sec),
m = partition mass/sq cm,

* The numerical measure of the reduction of sound intensity level is expressed by the term transmission loss, which is defined as ten times the logarithm to the base 10 of the reciprocal of the transmittivity, T, which is the ratio of the rate of transmitted sound energy away from the partition to the rate of flow of incident sound energy.

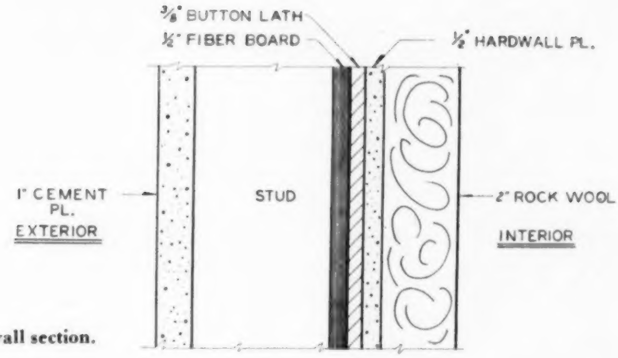


Fig. 7. Exterior wall section.

F_0 = resonant frequency of partition,
$= \frac{1}{2\pi}\sqrt{\frac{S}{M}}$
s = stiffness of wall (dyne/cm), and
M = mass of wall (g).

When r is small compared to R, and the exciting frequency is considerably higher than the resonant frequency of the partition, the transmission loss becomes:

$$T.L. = 20 \log \frac{\pi f m}{R}$$
$$= -22.44 + 20 \log Fm$$

It has also been learned that when a single wall (Fig. 7) of a given weight is constructed, the transmission loss of this wall can be increased considerably if the wall is made of two or more different layers or skins. It is true that the surface which is struck by the sound is set into vibration as a diaphragm, but this energy has to be transferred to the next layer and then to another layer, and so on. By proper combination of the materials, this energy transfer may be made quite small, which thereby increases the transmission loss of the wall. By the same token, of course, it becomes rather difficult to predict in advance the transmission loss of a wall when it is constructed in a complicated manner by using several different building materials separated from each other by air layers.

It is also often believed that the transmission loss of a wall can be increased considerably by the introduction of a filler between the outside and the inside layer of a stud wall. This may be of advantage for lighter partitions, but for heavier construction an empty air space is acoustically often the best insulator. This is particularly true if the filler is solid so that it will pack down and act as a tie between the two surfaces.

In the new Republic stages, the interior adjacent walls are double walls constructed with isolated footings (Fig. 6) and the outside walls are of single-wall construction (Fig. 7). Sound transmission loss tests conducted on the walls between stages showed a loss of 48 db at 100 cycles and 59 db at 300 cycles. Above 300 cycles the transmission loss was in excess of 59 db and could no longer be measured with the equipment available for the purpose. Sound transmission loss tests conducted on the outside walls of the stages showed a loss of 55 db at 1000 cycles.

Completing each stage are electric lighting facilities providing two circuits of 2000-amp capacity. The panel boards are interconnected between stages so that a third d-c circuit of 2000-amp is available at any of the four stages. The electric power and service are controlled in each stage by a central three-panel board which contains three-phase power, single-phase power and single-phase for stage overhead lights. These panels also contain all relays which operate the overhead fans, red warning lights, telephone and drinking fountains. The main and subfeed breakers are connected to this panel so that any maintenance or trouble shooting is confined to the one central area.

Each stage is equipped on the exterior with a new-type rotating warning light to control heavy street traffic. This exterior warning light consists of a special motor-driven double reflector light unit which is similar in design to that used by certain types of police cars. Permanent work lights with 750-w reflector fixtures are standard equipment on each stage to provide ample work light, eliminating the necessity of handling portable work lights for set construction purposes.

In closing, we would like to express appreciation to our associates whose efforts made this structure possible, particularly, Al Merrill, W. O. Watson, Jim Phillips and Tex Steiner.

Color-Compensating Light Changer

By JAMES W. KAYLOR
and A. V. PESEK

The need for an adequate color-compensating light source for direct color printing resulted in the development of a flag-type subtractive light changer, complete with lamp, optical system, filter pack and blower system, and modulating the light path with four interchangeable flag units. Each unit is mounted with the proper filters and is actuated by an electrical-signal device working from a perforated tape. This unit has been adapted to continuous, step and optical printers.

To HANDLE the increasing demand for direct color prints, color negative to color positive, an adequate color-compensating light source which could be adapted easily to the various types of film printers involved was required by the Color Corporation of America. For easy adaptability it was required that the light source and light changer be a self-contained unit, separate and complete from the type of printer it was to be used on. It was also decided that a subtractive filter system would be used to correlate this new light source with a method of printing already in use in the laboratory. The resultant design produced a flag-type subtractive light changer which is shown in Fig. 1 as adapted to a Bell & Howell Model D printer. The single light source consists of a 750-w projection lamp with an Eastman Master Slide Projector condenser unit. To concentrate the light beam at the film plane and to insure an acceptable flat field a series of three additional relay lenses was designed to be installed along the light path and to fit between the filter flag units. This gave sufficient light intensity at the film plane to allow a printer speed of up to 125 ft/min. To aid in removing heat from the light beam for protection of the filters, a heat-reflecting mirror was placed just forward of the basic condenser system between the light source and the first filter flags. Four flag units are used, one each to modulate the cyan, magenta and yellow components, and the fourth to correct for overall density. Each unit consists of five filter flags, the filters being 0.025, 0.05, 0.10, 0.20 and 0.40 density, respectively. These filters in the proper combinations give a range of 32 printer points and, considering the three color units together with the neutral density unit, a total range of 64 printer points obtains.

To reduce the range necessary for normal printing, a slide is provided for the insertion of a basic filter pack for overall general color correction.

The four flag units, Fig. 2, are identical, with the exception of the mounted filters. This gives interchangeability and allows one or two spare units to serve in case major repairs may be necessary during an operational period. To provide for the fastest possible filter change between scenes, each flag is operated by two solenoids, one to bring the flag into the light path and the second to remove it. The solenoids actuate the flag through a system of toggle joints, Fig. 3, and a light spring pressure is used to hold the flags in either position. This system allows the solenoid to be energized for extremely short periods with two to three times the specified voltage of the solenoid.

The pulse system of actuating the flags allowed a signal device to be designed which would be presetting, eliminating the necessity of rapid changes of the signal tape. The signal device consists of the signal tape with contact fingers and roller contact bar, a stop-motion tape-advance mechanism, a system of signal relays, one for each of the flags and actuated by contact of the fingers through the perforated signal tape, and a bank of four heavy-duty pulsing relays, one for each flag unit and actuated by the breaker box on the printer.

Sequence of operation is: The signal tape which has been perforated with the proper combination of contact holes in sequence, one for each filter required, is threaded between the contact fingers and the roller contact bar. It is manually advanced until the first row of holes is aligned between the contacts. The proper fingers making contact through the holes close the respective signal relays into the IN position. The signal relays actuating the unwanted filters remain open or in the OUT position. (The signal relays are double-throw relays making contact in either the open or closed position.) The printer is started and as the light-change notch for the first scene trips the breaker box, the breaker box closes the four pulsing relays which energize the proper IN or OUT solenoids, depending on whether the respective signal relays are open or closed. This moves the required filter flags into the light path, while the unwanted filter flags are held out by the action of the OUT solenoids.

At the same time that the pulsing relays are actuated, the breaker box also actuates the stop-motion advance mechanism which then advances the tape to the next light change. The contact fingers reestablish contact through the new row of holes, setting up the signal

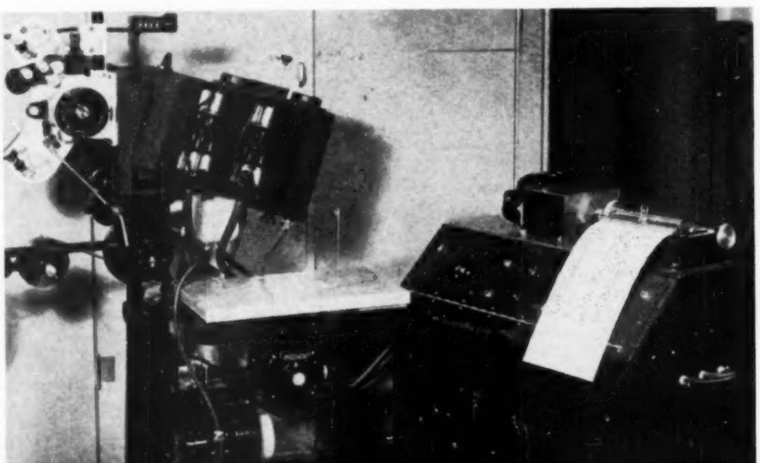


Fig. 1. Color light changer and signal device.

Presented on May 6, 1954 at the Society's Convention at Washington, D. C., for the authors (both formerly of Color Corp. of America), James W. Kaylor, Fonda Corp., Glendale, Calif., and A. V. Pesek Pathé Laboratories, Inc., 6823 Santa Monica Blvd., Hollywood 28.
(This paper was received on March 29, 1954.)

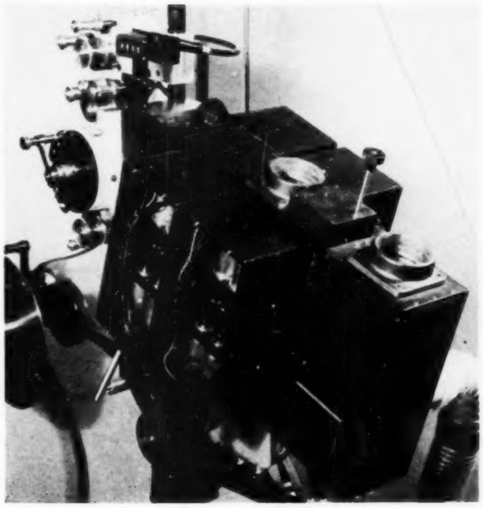


Fig. 2. Color light changer showing four flag units in staggered position.

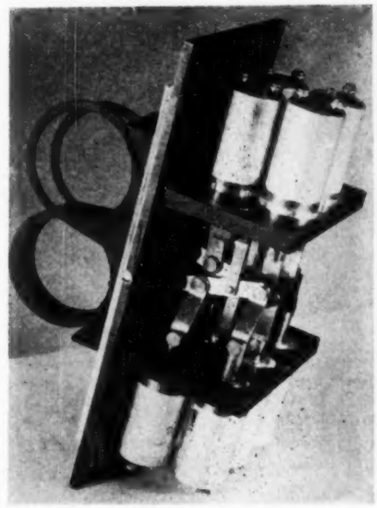


Fig. 3. Typical filter flag unit.

relays in the desired order for the next scene, and when the breaker box is actuated by the film notch the required filter flags are either held in the light path, held out of it, withdrawn from the light path or moved into it, as required for the scene.

This sequence of operation is continued until the end of the reel, where a notch placed at the end of the last scene actuates the signal device and all flags are cleared from the light path as there are no contact holes punched in the signal tape.

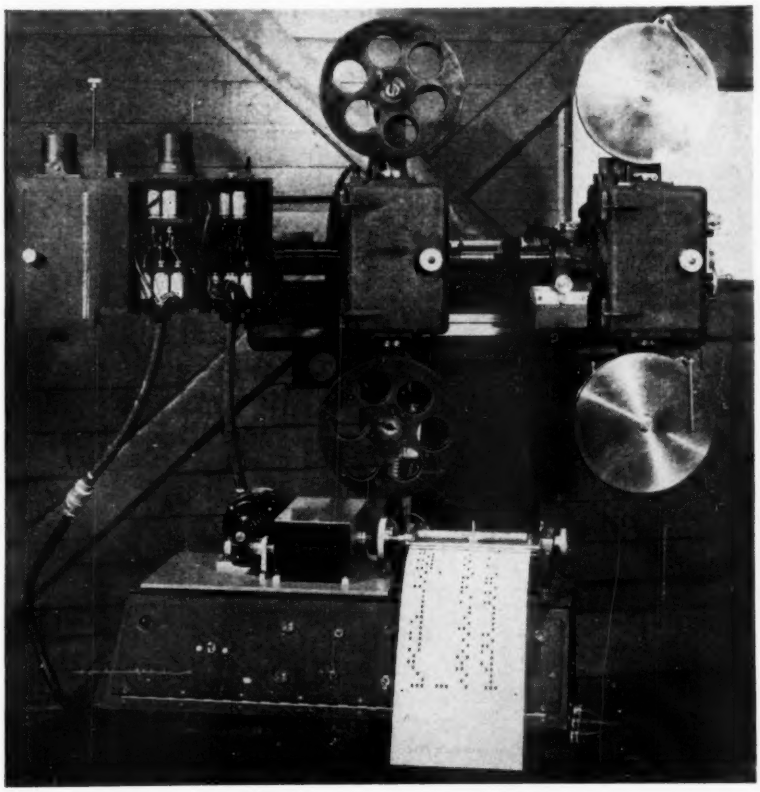


Fig. 4. Color light changer adapted to an optical printer.

In the signal device, 110 v, a-c is used as the signaling current to close relays, actuate and drive the advance mechanism, and close the pulsing relays. To actuate the flag solenoids, 220 v, a-c is used, the circuit being opened and closed by the four heavy-duty pulsing relays. Using a standard Bell & Howell notch, at a film speed of 90 ft/min the duration of the pulse current is approximately $\frac{1}{18}$ sec. It has been found that under normal operation, the 24-v, d-c solenoids used do get warm but do not overheat. The speed of the filter flags is such that at a film speed of 90 ft/min on a Bell & Howell Model D printer approximately one-fourth of a frame may be mislit when the scene-to-scene correction made is large.

The color-compensating light source and signal device described in this paper has been adapted for use with step printers, and an optical printer, Fig. 4, as well as with the Bell & Howell Model D printer herein described. The light changers have been in use for some time at this date and function very well.

Acknowledgment

We wish to acknowledge with thanks the cooperation and help given by Harry P. Brueggemann and John Fritzen in the development of this equipment.

Electronic Light-Change Device

By HARRY P. BRUEGGEMANN

This paper describes a means of actuating scene-to-scene light changes in motion-picture printing. A conducting tape is applied to the printing negative by a special punch. This cues an electronic device which fires the light-changing mechanism. The electronic device has a delay circuit which assures adequate time for the completion of the light-change operation.

For a long time there has been a need in the motion-picture industry for a light-changing method which does not require notching negative. Preferably, too, this method should be such that all negative preparation required for its operation is only temporary and can be removed when the negative is printed out. Several years ago a design for a magnetic light-change method was circulated through the industry, but it was not universally adopted for 35mm work. The reason for its failure to catch on may be because of the increased maintenance required on the electronic components as compared to the simple Bell & Howell breaker box, the cost of conversion to such a system or the lack of economic pressure on the laboratories to stop notching negative. Then, too, there are the inevitable "bugs" to be worked out of anything new.

In 16mm color work, there is a very definite economic pressure to keep original material unnotched, since much Kodachrome is used and re-used as stock material, and cannot be successfully duped without losing a large amount of color quality. There are many magnetic and "conducting tape" light-change systems used on 16mm color printers. The system described here is offered as a reliable device, with a quickly applied and easily removable conducting tape being the negative preparation, and usable on 35mm as well as 16mm.

To prepare original Kodachrome for printing, it is run through a synchronizing machine and tape punch (Fig. 1). The tape punch is designed to hold the Kodachrome in position while a piece of aluminum tape, 0.095 in. by 0.200 in., is punched out of a roll of aluminum adhesive tape and applied to the emulsion side of the Kodachrome. The punching and application are done in one motion, and by means of register pins in the holding device the tape is applied between the perforations of the Kodachrome, 0.005 in. away from the edge of the film as shown in Fig. 2. The holding device has two positions,

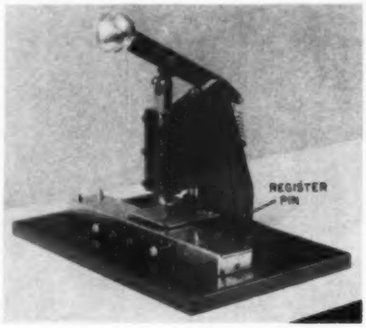


Fig. 1. Tape punch, showing punch and die aperture and register pin.

one to apply the tape on the track side and the other to apply on the non-track side. The synchronizing machine, together with a cue sheet or workprint, locates the exact frame at which the tape should be applied.

The printer is a Bell & Howell Model J, equipped with a split roller and the electronic chassis as seen in Fig. 3. The chassis is located next to the drive motor underneath the motor mount table. Both flanges of the roller are split from the body of the roller and insulated from it (see Fig. 4). Each flange is electrically connected to one of the contact leads from the chassis: the inside flange to the dissolve-shutter lead, and the outside flange to the light-change lead. The center portion of the roller is grounded. This roller is located just above the main sprocket, in a position to take the original Kodachrome in thread-up. When a taped section of the film passes over the roller, it grounds the flange it contacts and thereby actuates the light changer or dissolve shutter. The actuation begins the instant the tape first touches the roller, and therefore, this event is the time reference point for the sequence of operations. The location of this point must be carefully controlled, especially for the light changer, in order that the light change always occurs at the frame line between scenes. This specification requires that the roller be close to the printing aperture, to minimize the effects of film shrinkage, although shrinkage can be almost eliminated as a source of trouble if the register pin of the tape punch is located at the scene-change point of the original Kodachrome. Then the tape is always applied at exactly the same distance from the scene change, no matter how badly the original Kodachrome has shrunk. This specification

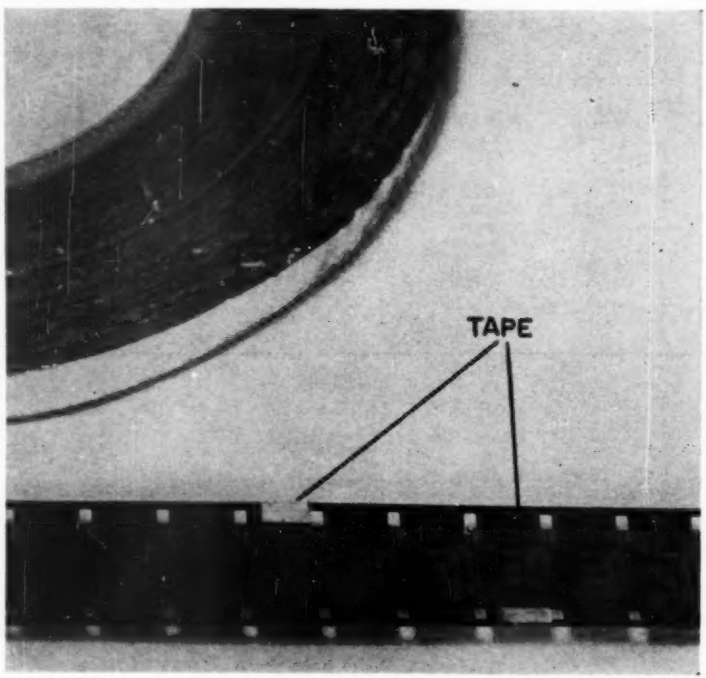


Fig. 2. Close-up of a segment of a roll of aluminum tape, and the tape applied to commercial Kodachrome.

Presented on May 6, 1954, at the Society's Convention at Washington, D.C., for the author, Harry P. Brueggemann, at that time with Color Corporation of America, now at Pathé Laboratories, Inc., 6823 Santa Monica Blvd., Hollywood 28.
(This paper was received on March 29, 1954.)

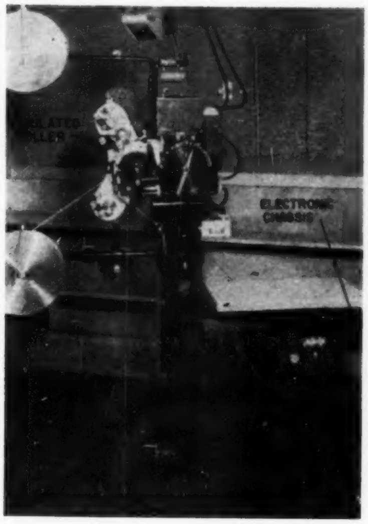


Fig. 3. Bell & Howell Model J Printer, showing the electronic chassis next to the drive motor and the split roller above the 4-in. sprocket.

also requires uniform thread-up procedures, with a uniform amount of wrap on the contacting roller.

Figure 5 is a diagram of the electronics involved which consist of simply a 120-v, d-c power supply, a 6-v, a-c heater power supply, a 6V6 tube, a "trigger" circuit and a relay. The trigger circuit actuates the relay through the 6V6 tube. The only unusual feature of this assembly is the time-delay system of the trigger circuit and the relay. The relay is built so that it holds in the closed position for about 0.2 sec after the power is removed. In the trigger circuit, there is an RC network which keeps positive voltage on the grid of the 6V6 for a period of time, and thus keeps the relay closed. In the standby condition, that is when the relay is open, the grid of the 6V6 is biased negatively by a 15-v battery, which with 120 v on the plate is sufficient to cut off plate current.

When the tape grounds the outside flange of the roller, the grid is biased positively by a 15-v battery, causing the 6V6 to conduct plate current and

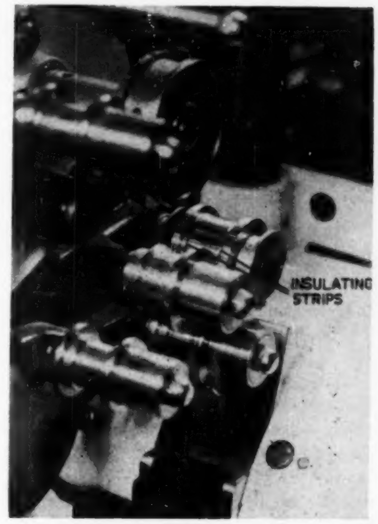


Fig. 4. Close-up of split roller mounted on the Model J Printer showing the thin insulating strips between the center portion and the outside flanges.

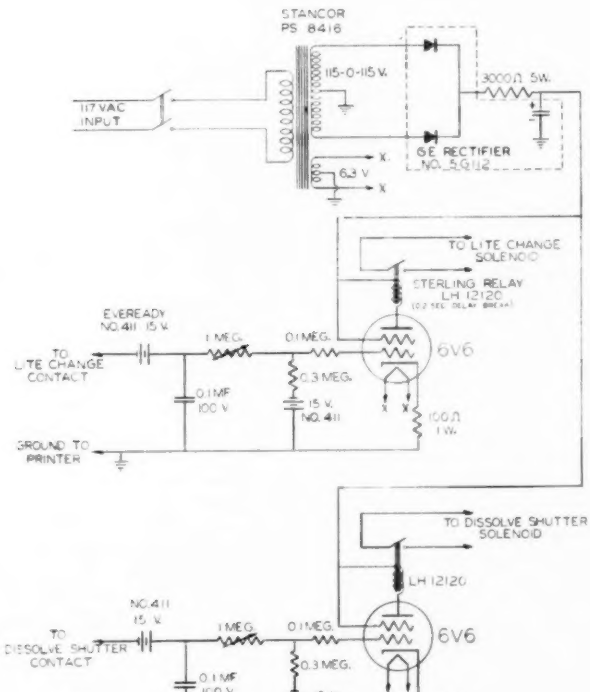


Fig. 5. Wiring diagram of the electronic chassis.

closing the relay. This positive bias also charges a condenser which holds positive voltage on the grid of the 6V6 after the tape has passed by the roller. The condenser bleeds off through a delay potentiometer, and this potentiometer controls the time required for the grid to drop back to cutoff voltage. Thus the potentiometer can be set to allow adequate time for all phases of the light-change or dissolve-shutter functions to be completed, and still not require too great a distance between tapes to allow time for the unit to reset itself. In the 120-v power supply circuit there is a 3000-ohm, 5-w resistor. This not only acts as a filter but also helps extinguish the plate current as the 6V6 grid drifts towards cutoff voltage. In other words, the power supply should have as high an output impedance as possible and still deliver enough power to close the relay.

Maintenance of the electronic equipment is very small. The battery life is almost shelf life, but it is advisable to check battery voltage once a week. For this purpose a d-c voltmeter with a four-position switch can be installed on the equipment. The other components, including the relay, should operate for years without giving trouble.

Acknowledgment

We wish to acknowledge with thanks the cooperation and help given by James W. Kaylor and John Fritzen in the development of this equipment.

Synchronized Recordings on Perforated Tape

By WARREN R. ISOM

A button-on recorder-reproducer unit for a 16mm commercial projector using perforated ¼-in. magnetic tape as the medium for sound is described. The performance of the unit recommends perforated tape as a satisfactory medium for synchronized recording.

WITH THE advent of ¼-in. wide magnetic tape, a search was begun for the best and most simple method of making synchronous recordings on this medium. The pages of the *Journal* of the SMPTE for several years past have carried the records of the success that has been gained. Many of these achievements are examples of engineering at its best. Some of the techniques employed represent the highest developments in the recording art and reveal great application of engineering knowledge in the actual working equipment.

However, due to the thinness of the medium, which is only 2 mils thick and no more than ¼-in. wide, the simplest and most obvious method of accomplishing the job or finding the answer has been largely overlooked. That answer is to put holes in the tape and sprocket drive it. The object of this paper is to describe the laboratory use of this method to record sound synchronously with the picture on motion-picture film and to suggest the extension of this method to other applications.

Description

A button-on recorder-reproducer unit was built up for use with a 16mm motion-picture projector. Figure 1 is the overall view of the equipment. This is a partial view of a commercial 16mm projector with a button-on sprocket-hole tape adapter attached in the same manner as the upper reel arm. The button-on unit carries three spindles, one for the reel of film and one each for the tape supply and take-up reels. This particular unit was made up for 1600-ft film reels and 1200-ft tape reels. Associated with the reels is the tape-propelling and recording-playback head.

The best way to describe these parts and their function is to follow the tape path from the supply reel to the take-up reel as seen in Fig. 2. The tape is first threaded around a dancing S-idler to give some degree of isolation from the irregularities of the supply-reel motion and to protect the tape itself from the shock of starting. The tape is guided onto a stabilizing inertia-loaded capstan and secured to it by a viscous-drag pressure roller. Next, the tape is guided across the head to the principal propelling capstan, which is heavily inertia-loaded and is isolated from the tape-driving sprocket by a damped sprung-idler. The tape is threaded around the driving sprocket. From the sprocket, the tape passes across a guide roller to the tension-sensing idler and from there to the take-up reel.

Fig. 1. The button-on sprocket-hole tape recorder-reproducer mounted on a commercial 16mm projector in place of the upper reel arm.

After the tape has been threaded, the film is threaded through the projector so that it engages the film-driven sprocket of the button-on unit. This sprocket which is driven by the film shares a shaft with another sprocket which propels the tape. The tape sprocket is so located that the recorded magnetic track overlaps the soundtrack area of the film. This precludes the use in this place of a sprocket for double-perforated film but preserves the picture area of the film from damage. It also retains the use of the film as a hold-down for the tape and makes positive its drive by the sprocket.

The reverse side of the unit is shown in Fig. 3. The larger flywheel is on the tape-propelling capstan. The smaller one is on the stabilizing capstan. The take-up reel is driven by a woven belt by the pulley on the film-driven sprocket shaft. The take-up is constant tension by virtue of the interlinkage between the tape tension-sensing idler and the take-up belt tightening idler.

The rewind of both the film and tape is accomplished simultaneously and is powered by the regular rewind mechanism of the projector. A system of override clutches eliminates rotational interference between the spring-belted film-and-tape supply spindles during playback. A snubbing brake on the tape spindle shaft was found useful.

Operation

From Fig. 2 it is seen that the operation of the tape button-on unit is essentially that of passing the tape over a head while it is tensioned between two capstans. The viscous-drag pressure roller on the stabilizing capstan supplies the resistance against which the tape is tensioned. The viscous nature of this resistance damps the tendency of the flywheel to oscillate against the compliance of the tape. The propelling capstan is isolated from the driving sprocket by the viscous-damped sprung idler. This damping controls the tendency of the larger flywheel to oscillate.

The electrical analog to this filtering system can be displayed (Fig. 4) as a low-pass filter heavily damped and with provisions to by-pass much of the higher frequency disturbance from the driving sprocket.

In use the unit is first threaded, with care being exercised to place the start marks over the magnetic head. Next, the film is threaded, also with care being exercised to place the start mark in the aperture of the gate. Other start

Presented on May 5, 1954, at the Society's Convention at Washington, D.C., by Warren R. Isom, Bldg. 10-4, Radio Corporation of America, Camden, N.J.
(This paper was received on May 13, 1954.)

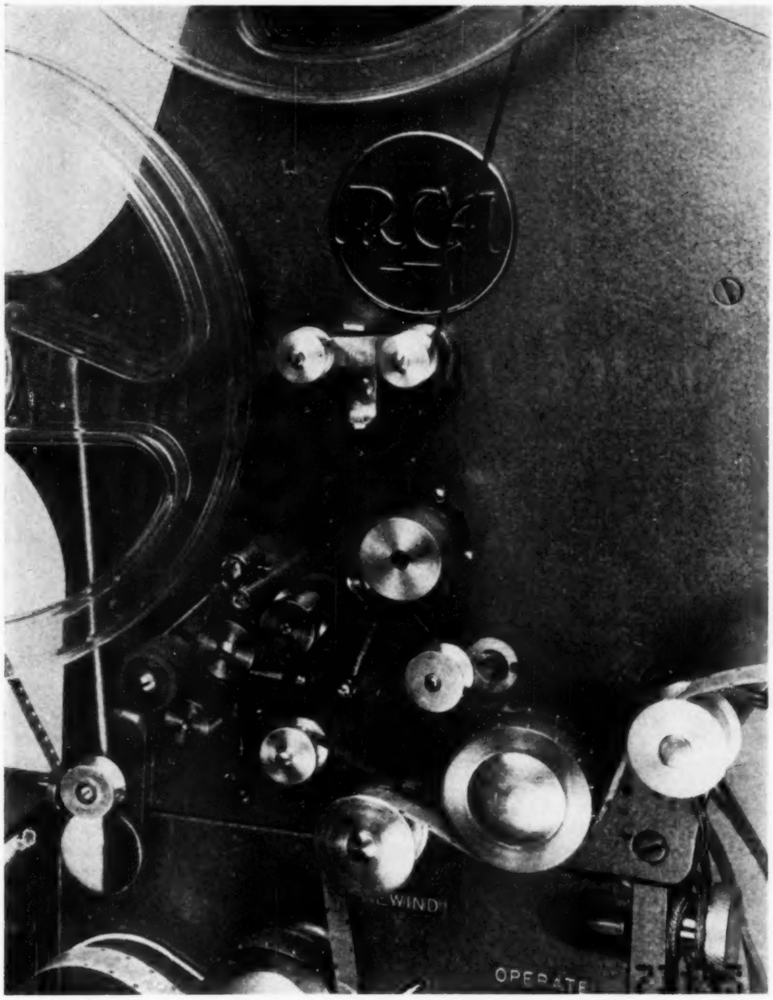


Fig. 2. Close-up of the sprocket-hole tape transport.

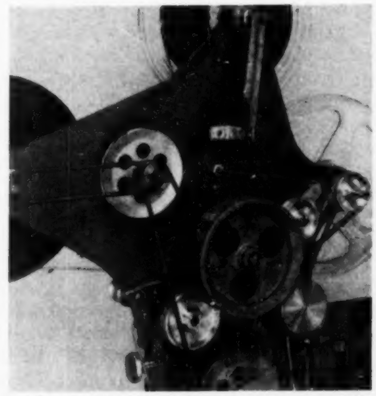


Fig. 3. The dual-flywheel tape stabilizer; also the tape take-up and the film-tape rewind mechanism.

references can be used — such as the sprockets. The equipment is then ready for use, either for recording or for playback, as previously selected. The starting time for the button-on unit is a matter of 5 sec or less. Proper threading always insures perfect synchronization. However, threading errors are easily adjusted during operation by the simple expedient of advancing the film in the gate by engaging the top or bottom intermittent loop with one's finger. The use of sprocket-hole tape literally gears the tape to the film or to time for time-synchronous recording.

Performance

The performance of this experimental unit has been very good. Wow and

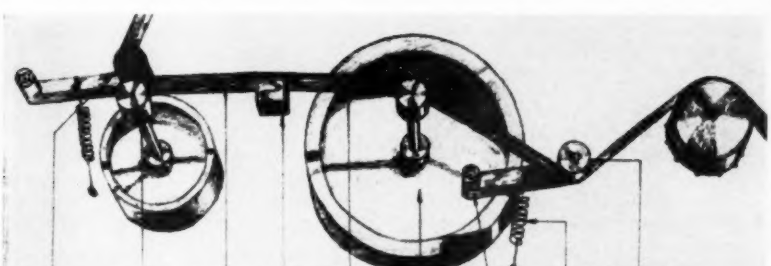


Fig. 4. The electrical analog of the tape-filtering system.

Fig. 5. The record-playback head, with the point of a lead pencil for reference.

flutter experienced has been of the same order as with 16mm optical soundtracks. Noise of course, has been considerably and consistently lower. The signal-to-noise ratio was so high that there was no incentive to use a track of maximum width. The head employed is 80 mils wide with a half-mil gap. Figure 5 shows the head in its special mount. Frequency response of the system was good to 8000 cycles.

No evidence was found of polygoning even when the tape was explored within a few thousandths from the sprocket holes. The tape wears well. Originally it was thought that tape wear would limit the use of the idea to specialized uses even if the polyester bases were used. In practice, however, the acetate base tape was found to be very satisfactory even in this unit which had no great provision for relieving the strain on the tape during the starting period. The starting time was normal for the projector; that is, in the order of 5 sec.

The Perforator

The first difficulty encountered was that of finding a source of sprocket-hole tape. The first roll of tape was perforated by a film laboratory and it served during the entire development of the project. However, it was deemed advisable to build a very simple perforator. Figure 6 shows the machine. The tape is propelled through the machine over a die. An eccentric-operated punch perforates the tape as it is stepped along by an intermittently rotated sprocket. Figure 7 shows that the tooth-to-tooth intermittent motion is imparted to the sprocket by a walking-beam pawl actuated by a plunger which rides on another eccentric. This pawl eccentric is out of phase with the punch eccentric. A slipping-belt drive was used for the take-up. Idlers were inserted to absorb the intermittent action of the perforating. The perforator was driven directly by a four-pole shaded-pole motor. This gave 27 perforations a second. The tape perforated by the machine was judged to be entirely adequate. In no way were the inaccuracies of this simple perforator reflected in the recording or play back. The requirement of accuracy for the perforations is much lower than that for film upon which picture steadiness depends. The possession of a perforator is no longer a necessity since perforated tape is now available from tape manufacturers.

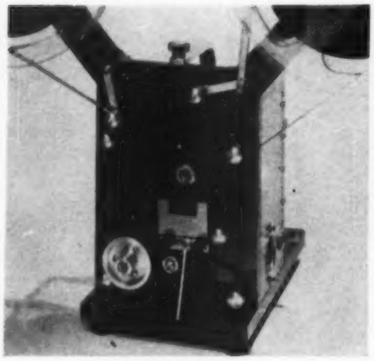


Fig. 6. The perforator.

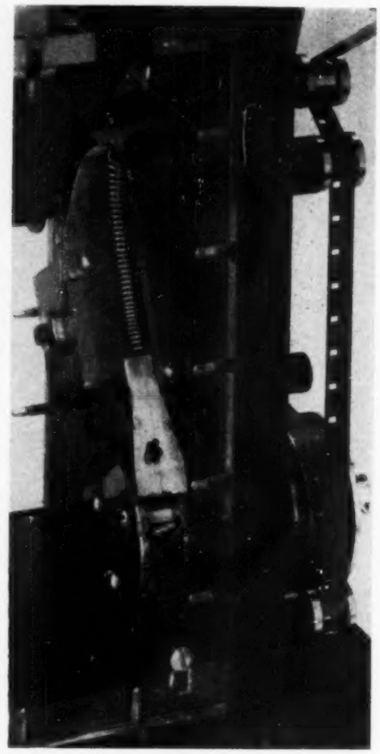


Fig. 7. The walking-beam pawl intermittent drive for tape advancing sprocket.

Future Use

The good performance of sprocket-hole tape as a medium for synchronous recording, its simplicity of method and the ease of operation insures that it will be widely used. However, at the outset some decisions as to the size, shape and location of the holes should be made after full consideration of all the factors involved. An early decision could eliminate confusion later. This medium is a worthy one and offers an easy solution to many difficult recording problems.

Acknowledgment must be made of the assistance given by members of the RCA Optics, Sound and Special Engineering Section at Camden, particularly by Walter H. Erikson and George J. Rogers. Also, a great debt of gratitude is owed to those who found ways of perforating that first roll of tape upon which this program depended so heavily.

SMPTE 76th Convention – October 18–22 – Los Angeles

The prophetic words of Horace Greeley once again apply as the SMPTE invites its members and friends to "Go West" for the 76th Semiannual Convention to be held at the spacious and luxurious Ambassador Hotel in Los Angeles during the week of October 18–22, 1954.

The topic slated for chief interest in the convention is color television with its many ramifications in the fields of equipment design, color-television film-production techniques, and laboratory practices for color films. The problem of supplying films suitable for both monochrome and color television will receive appropriate attention.

A large and interesting equipment exhibit is planned. Manufacturers desiring to participate should immediately contact Thomas J. Gibbons, SMPTE Exhibit Chairman, 446 North La Brea Ave., Hollywood 36, Calif., for space reservations. Other areas of interest such as high-speed photography, magnetic striping, drive-in theaters, etc., will maintain their usual prominence and attention.

Officers of the papers committee are:

W. H. Rivers, *Chairman*, Eastman Kodak Co., 342 Madison Ave. New York 17, N.Y.

J. E. Aiken, *Vice-Chairman*, 116 N. Galveston St., Arlington 3, Va.

S. W. Athey, *Vice-Chairman*, General Precision Laboratory, 16 S. Moger Ave., Mt. Kisco, N.Y.

C. E. Heppberger, *Vice-Chairman*, 231 North Mill Street, Naperville, Ill.

G. G. Graham, *Vice-Chairman*, National Film Board of Canada, John Street, Ottawa, Canada

J. H. Waddell, *Vice-Chairman*, Wollensak Optical Co., 850 Hudson St., Rochester 21, N.Y.

Chairman for High-Speed Photography for the 76th Convention is Carlos H. Elmer, 410B Forrestal St., China Lake, Calif.

If you or someone in your organization has a potential paper for this program, word will be welcomed by the writer or by any of those listed above. Help and advice are also forthcoming upon request to any member of the Papers Committee, which is given in the April 1954 *Journal*, p. 328.—*Ralph E. Lovell*, Program Chairman for the 76th SMPTE Convention, 2743 Veteran Ave., Los Angeles 64, Calif.

Engineering Activities

A high level of committee business was reached during the meetings of the technical committees during the 75th Convention, May 3–7, 1954. The highlights are reported below.

Color Committee: Progress was reported by W. R. Holm, Chairman of the Subcommittee formed to prepare a monograph on the Elements of Color Cinematography. An outline of the material to be covered has been prepared and authors have been lined up for several of the chapters. It is expected that the remaining chapters will be assigned shortly.

A new Subcommittee to develop a standard of light quality in color film projection was formed and will be chaired by A. M. Gundelfinger. The Subcommittee was specifically charged with the responsibility of selecting a meaningful, easily applied method of specifying and measuring the color of the illumination, deciding what would constitute a preferred spectral quality in terms of the measuring system.

In addition the Committee made plans to explore the possibility of establishing a processing system suitable for all types of color negatives.

Film Dimensions Committee: A standard for the film used in the CinemaScope process was the main order of business and the Committee voted to draft and circulate a standard for consideration of the full committee.

Film Projection Practice: There was discussion of sprocket dimensions for the narrow CinemaScope perforations but no specific conclusions were reached. Sprocket dimensions for standard perforations were also reviewed and agreement was reached on revision of the applicable American Standard, Z22.35-1947. Revision of American Standard, Z22.4-1941, was also approved and a proposal will be circulated to the full committee shortly for letter ballot.

Screen Brightness Committee: A screen brightness standard for 16mm review rooms has been under consideration by this committee and the Laboratory Practice Committee for several years. At this meeting, the deadlock over the contending proposals, $10 + 4 - 1$ ft-L vs 7 ± 2.5 ft-L, was finally resolved and agreement was reached on a compromise value of 10 ± 2 ft-L. This is now out to letter ballot of both committees.

A survey was initiated to determine the existing screen brightness of drive-in theaters. It is expected that the survey results will provide a basis for drafting a standard.

Consideration was given to the question of stray light and its effect on picture quality. A subcommittee is to be formed to determine the maximum acceptable level of stray light and it is intended that this specification be eventually included in the standard for theater screen brightness.

16 & 8mm Committee: The ballots on PH22.15 and PH22.16 (16mm Film Perforated One Edge, Usage in Camera and Projector) were closed and the Chairman was authorized to submit these two standards to the Standards Committee.

PH22.9 and PH22.10 (16mm Film Perforated Two Edges, Usage in Camera and Projector) were also reviewed. It was indicated that the ballots on these standards will also be closed shortly.

In addition, the committee reviewed its projects on 600-ft and oversized reels, travel-ghost test film, projection practice booklet and a test film for 8mm film projectors, and made plans for furthering the work of all these projects.

Sound Committee: Discussion was centered on test films for the CinemaScope process and on the requisite standards. Specific assignments were made for drafting such standards which will then be circulated as proposals to the full committee for letter ballot.

Magnetic Recording Subcommittee: The 16mm combination Optical-Magnetic Soundtrack proposal received considerable attention and agreement was reached to process it with minor revisions as a Society Recommended Practice rather than as an American Standard.

Specifications on 16mm and 35mm Magnetic Azimuth Test Films were reviewed and the decision taken to continue processing the 35mm film standards without change but to revise the 16mm proposal by specifying a square wave rather than sinusoidal recorded signal.

Favorable comment was received on the 16mm multi-frequency test film which has been in use for some six months and the Subcommittee agreed to standardize the specifications of this test film.

Progress was noted in the Navy Research Project to establish methods of calibrating Magnetic Sound Test Films.

Television Committee: Test films, slides and charts for color television completely occupied the time of this group. The general concepts were explored and a task force was appointed to work out the details.

Television-Studio Lighting Committee: Standardization of the varied and growing lighting terminology has been given a high priority in the work of this group. A first step in this direction has been taken by formulating the definitions of ten of the most commonly encountered terms and the group decided at this meeting to circulate these definitions to all television stations for industry-wide review and comment. It is hoped that this will both improve the work on nomenclature and lay the basis for broadening industry representation and and participation in all the activities of this committee.—*Henry Kogel*, Staff Engineer.

Section and Subsection Meetings

One of the most successful meetings, regional or otherwise, in the **Central Section's** history was held on April 15 at the Calvin Company in Kansas City, Mo. This meeting followed the three-day Calvin Workshop held on their sound stage. Over 200 members and guests were present, representing all but a few of the states in the Central Section.

The meeting was also outstanding for its program. The morning session opened with a paper by Richard H. Ranger, President of Rangertone, Inc., on "Utilizing Cue-Tape in 16mm Production." Everett Miller, of RCA, followed up with two papers: "A High-Definition Kinescope Recording System," and "Economies in Magnetic Recording."

After the papers, a symposium was held

on developments in new screen techniques. Trends in Hollywood were described in detail by Emery Huse of the West Coast Division Motion Picture Film Dept., Eastman Kodak Co. Ernest Wildi, Manager of Bolex-Kern, described his 16mm stereo system. Bell & Howell's new 16mm wide-screen production technique was reviewed by John Weber, Jr., Manager of the B & H Sales Engineering Dept. Finally, Pan-Screen was announced by Don Smith, Sales Manager of Commercial Picture Equipment Co.

The May meeting of the Section was held on May 13 at the Western Society of Engineers Building, Chicago. The entire evening was devoted to a talk on "The Role of Photography in Atomic Research," by Dr. Warren Everote, Director of Research and Production, Encyclopaedia Britannica Films, Wilmette, Ill. Dr. Everote illustrated his talk with a large number of well-chosen films excerpts which provided vivid emphasis for his comments on atomic energy, photographic techniques, cyclotron operation, cloud chamber, radio activity evaluation, etc. In addition to film excerpts illustrating a 3-D television method of evaluation used at the Argonne Laboratories, three complete films, *Operation Nevada*, *Operation Greenhouse* and *Operation Ivy*, were shown to the group of 65 members who attended the meeting.

Through the courtesy of Paramount Pictures Corp., the Central Section was invited to attend the Midwestern demonstration of VistaVision held at the Chicago Theatre on Wednesday, June 2. Special invitations were dispatched to members in this area advising them of these arrangements. It was felt that this would provide an opportunity for members who did not attend the Washington meeting to see this new wide-screen production process. Over 100 members attended. As was the case in Washington, the quality of the VistaVision presentation was excellent and well received by all.

One of the most successful meetings of the year was enjoyed by the Section on June 10 prior to summer adjournment. This meeting was noteworthy not only for the very excellent program, but also for the fine dinner at Stouffer's that preceded the meeting. The Committee feels that the pre-meeting dinner is a very important part of each program, and the attendance at Stouffer's would indicate that steps are being taken in the right direction.

George Ives, of the engineering staff at WBKB-TV in Chicago, led off the meeting by discussing the terms normally used in color television, and gave the 80 members present a comprehensive list of nomenclature. During his talk, Mr. Ives explained in general terms the different methods of color transmission, with emphasis placed on the various types of film transport. Film projection using a flying-spot scanner system was compared with the 3-vidicon tube method.

The last part of the meeting consisted of a paper entitled "Fundamental Make-Up Practices for Motion Pictures and Television," presented in excellent fashion by Syd Simons and Jack DuMont. Mr. Simons is an independent make-up artist, and Mr. DuMont is head make-up artist at Wilding Picture Productions. After explaining the importance of the art and its various applications to motion pictures and television they proceeded to make up a live model in what proved to be a most effective demonstration.—*K. M. Mason*, Secretary-Treasurer, Central Section, 137 N. Wabash Ave., Chicago.

The **Pacific Coast Section** held its April meeting at the NBC Studios in Hollywood on the evening of April 27, with 220 members and guests present. The program consisted of a symposium on the subject of television newsreel operations.

Roy Neal of NBC described the procedure followed at NBC in the production of routine and special-event newsreels. Frank La Tourette of CBS described his studio's news service organization which was set up last September for network and syndicate distribution. He discussed the effect on shooting, editing, script writing and televising imposed by the basic "immediate deadline" requirement which is characteristic of television newsreel activities.

Robert Allison of KTTV discussed the special problem connected with local news coverage. He explained the use of "beeper and phone" interviews, stock footage and stills in covering out-of-town news in the local television studios. The special problems of United Press Movietone News were discussed by Art de Tita, of that organization. He screened a series of outstanding spectacular news shots collected over a period of many years.

A lively question and discussion period followed the planned program. Jack DuVall, the program chairman, has been doing an outstanding job in arranging the programs for this year. With a careful eye on subjects of interest to both motion-picture and television people he has provided two programs on each of these general subjects so far this year.

The May meeting of the Section was held on Tuesday evening, May 25, in the Paramount Studio Review Theatre, Hollywood. Approximately 245 members were present.

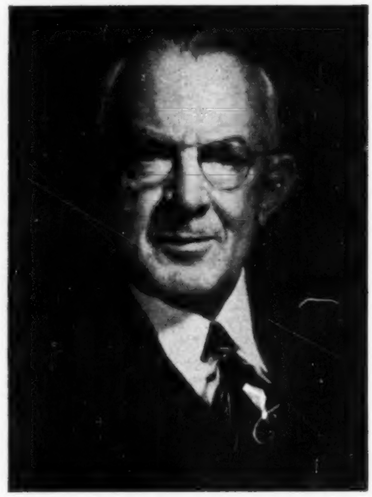
William Milwitt of RCA Laboratories discussed and demonstrated various applications of transistors in audio and radio receiver equipment. The very active question and answer period after the presentation was indicative of the great interest of the membership in this new device.

John G. Frayne of Westrex Corp. reported on his recently completed trip around the world in which he visited 40 motion-picture studios and 30 typical theaters in 12 countries of Asia and Europe. Of particular interest were Dr. Frayne's remarks regarding the impact of recent Hollywood technical advances on motion-picture releases in these countries. As an added special feature, three reels of the new Japanese feature film *Gate of Hell*, winner of the 1954 Best Picture Award at the Cannes Film Festival, were shown. This film was made available through Dr. Frayne's contact in Tokyo with Mr. Nagata, president of Daiai Studios.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, c/o Westrex Corp., 6601 Romaine St., Hollywood 38.

The **Southwest Subsection** held a meeting on April 26 at Miller's Visual Aids, Fort Worth, Texas. The paper on "Evaluation of 16mm Professional Prints," given at the 73d Convention in Los Angeles by A. C. Robertson of Eastman Kodak Co., was presented to the meeting through the medium of tape recording and illustrated with film and slides.

Lon Fitzgerald, Visual Education Supervisor for the Texas Game and Fish Commission, gave the second part of the program. Mr. Fitzgerald discussed some of the interesting phases of his film production work and related experiences in stalking wild game with a Speed Graphic and 16mm movie camera. His talk was illustrated with color films.—*W. W. Gilreath*, Secretary-Treasurer, Southwest Subsection, 3732 Stanford St., Dallas, Texas.

Obituary



Dr. Loyd A. Jones, President of the Society in 1923–25, died unexpectedly at his home near Rochester, New York, on May 15. He had retired as chief physicist of the Research Laboratories of Eastman Kodak Co. on May 1. Actively engaged in research in the physics of photography for more than forty years, Dr. Jones acquired an international reputation for his work, especially in the fields of photographic sensitometry and in the psychophysics of vision.

During his 35 years of active membership with the Society, Dr. Jones served on many committees and was chairman of the following: Papers (1921–23); Standards (1928–29); Journal (1929–30). The Journal of the Society was initiated in 1930 largely as a result of the great deal of work done while he was chairman of the Journal Committee. For the year of 1930 he served as editor pro tem until a permanent editor was obtained. He also served for seven years on the Board of Editors of the Journal. From 1935–39 he served as Engineering Vice-President of the Society and directed the important work of its engineering committees.

His interest in problems related to motion pictures began in 1919 and continued actively up to the time of his death. In an interview in April 1954, he expressed the opinion that the following papers were historically his most important contributions to motion-picture engineering: papers on illumination of the motion-picture

theater; contributions to photographic sensitometry; contributions to the theory and practice of tone reproduction; papers on photographic efficiency of artificial light sources used in motion-picture studios; and papers (jointly with Dr. G. C. Higgins) on the microstructure of the developed photographic image including graininess, granularity, sharpness, acutance and resolving power.

In 1931 Dr Jones gave a series of comprehensive papers on the subject of photographic sensitometry at the Spring meeting of this Society in Hollywood, California. These were published later in book form and are still considered one of the basic references on the subject. Previous to 1930, very little use had been made of sensitometric control in motion-picture processing laboratories and it was Dr. Jones' hope, in presenting a fundamental discussion of the subject, that would result in wider practical usage of sensitometry for better control of photographic quality in motion-picture prints. It was encouraging to him, therefore, to observe the rapid expansion in the use of sensitometry in motion-picture laboratory practice that took place in the two decades following publication of his book. It is also worthy of note that one of Dr. Jones' most fundamental papers dealing with the theory of tone reproduction, with a graphic method for the solution of problems, was published in the Society's Journal in 1931.

A great deal of work was done at different times by Dr. Jones and his co-workers on the microstructure of the photographic image. As early as 1920 he constructed an instrument for the quantitative measurement of graininess, in which the graininess of a photographic deposit was evaluated in terms of the magnification required to see a structure in this deposit. According to Dr. Mees, "One of the difficult problems in the early days of photographic physics was the relation between the graininess of a deposit as observed under magnification and the granularity of the deposit itself." Dr. Jones began to work actively on this relationship in 1945 and he and Dr. G. C. Higgins were able to resolve the matter satisfactorily and to clarify and evaluate the relation between graininess and granularity.

Dr. Jones was born at York, Nebraska, on April 12, 1884, where he attended public schools and was graduated from high school in 1903. He received his Bachelor of Science degree in Electrical Engineering at the University of Nebraska in 1908; his Master of Science degree in Physics in 1910; and the honorary degree of Doctor of Science from the University of Rochester in 1933.

From 1908 to 1910 he was assistant in the Physics Department of the University of Nebraska, and from 1910 to 1912, assistant physicist at the National Bureau of Standards in Washington, D. C. The head of the department of physics at the Bureau was Dr. P. G. Nutting. In 1912, Dr. Nutting accepted an invitation from Dr. C. E. Kenneth Mees to join the newly organized research laboratory of the Eastman Kodak Company and Dr. Nutting took Jones with him as his assistant. In 1916, Nutting left the Kodak Research

Papers Presented at the Washington Convention, May 3–7

MONDAY AFTERNOON—Technical Session

C. E. Phillimore, Bell & Howell Co., Chicago, "The Historical Background of the 35mm Professional Camera."

Vice-Admiral Harold G. Bowen, USN (Ret.), Thomas Alva Edison Foundation, Inc., West Orange, N.J., "Thomas Alva Edison's Early Motion-Picture Experiments."

T. H. Miller and R. C. McClelland, Eastman Kodak Co., Rochester, N.Y., "Effective Use of Color Slides in Technical Lectures."

MONDAY EVENING—Black-and-White Cinematography

C. E. K. Mees, Eastman Kodak Co., Rochester, N.Y., "The History of Professional Black-and-White Motion-Picture Films."

Joseph Westheimer, Consolidated Film Industries, Hollywood, "Principles of Special Photographic Effects."

Ray Kellogg and L. B. Abbott, Twentieth Century-Fox Film Corp., Beverly Hills, Calif., "Some Special Photographic Effects Used in Motion-Picture Production."

TUESDAY MORNING—Theater Session

Charles W. Handley, National Carbon Div., Union Carbide and Carbon Corp., Los Angeles, "History of Motion-Picture Studio Lighting."

Willy Borberg, General Precision Laboratory Inc., Pleasantville, N.Y., "The Development of the 35mm Projector."

H. E. Bragg, L. D. Grignon and E. I. Sponable, Twentieth Century-Fox Film Corp., N.Y., "Design Considerations of CinemaScope Film."

C. Robert Fine, Fine Sound Inc., N.Y., "Perspect-A-Sound Integrator Unit."

Loren L. Ryder, Paramount Pictures Corp., Hollywood, "VistaVision."

TUESDAY AFTERNOON—Color Session

Gerald F. Rackett, Columbia Pictures Corp., Hollywood, "Color Cinematography, 1930–1954."

K. M. Carey, National Film Board of Canada, Ottawa, Ont., "Latensification of Multilayer Color Film."

R. C. Lovick and R. L. White, Color Technology Div., Eastman Kodak Co., Rochester, N.Y., "Factors Affecting Application of Soundtrack Developers to Color Films."

H. F. Ott and R. C. Lovick, Color Technology Div., Eastman Kodak Co., Rochester, N.Y., "High-Efficiency Air Squeegee and Sound-Developer Applicator for Color Films."

D. E. Grant and H. F. Ott, Color Technology Div., Eastman Kodak Co., Rochester, N.Y., "A Rapid, Automatic Stitch Splicer for Darkroom Operation."

WEDNESDAY MORNING—Sound Session

E. W. Kellogg, retired, formerly RCA Victor Div., Radio Corporation of America, Camden, N.J., "History of Sound Motion Pictures."

John G. Frayne, Westrex Corp., and B. N. Locanthi, Consultant, Hollywood, "Theater Loudspeaker System Incorporating an Acoustic Lens Radiator."

Kurt Singer and Robert V. McKie, Radio Corporation of America, Hollywood, "Cross-Modulation Compensator."

Warren R. Isom, Radio Corporation of America, Camden, N.J., "Synchronized Recordings on Perforated Tape."

Daniel J. Bloomberg, John E. Pond, Republic Productions, Inc., and Michael Rettinger, Radio Corporation of America, Hollywood, "Republic Studio Multiple Stage Design."

J. K. Hilliard and J. J. Noble, Altec Lansing Corp., Beverly Hills, Calif., "Improvements in Small Condenser Microphone Design."

WEDNESDAY AFTERNOON—16mm Projection Session

Malcolm G. Townsley, Bell & Howell Co., Chicago, "History and Development of 16mm Motion-Picture Equipment."

Philip M. Cowett, Navy Dept., Bureau of Ships, Washington, D.C., "The Navy Development Program for a Brighter Projector Light Source."

W. T. Anderson, Jr., Hanovia Chemical and Mfg. Co., Newark, N.J., "High-Brightness Xenon Compact Arc Lamp."

E. W. D'Arcy and A. C. Seda, Bell & Howell Co., Chicago, "Application of the Xenon Arc to the Armed Forces AQ-2(1) 16mm Sound Motion-Picture Projection Equipment."

E. W. D'Arcy and A. C. Seda, Bell & Howell Co., Chicago, "Qualitative and Quantitative Determination of Travel Ghost."

Arthur Cox, Bell & Howell Co., Chicago, "CinemaScope Lenses."

WEDNESDAY EVENING—National Archives Session

Josephine Cobb, National Archives, Washington, D.C., "Matthew B. Brady and His War Photography, 1861–1865."

THURSDAY MORNING—Technical Session

John I. Crabtree, Eastman Kodak Co., Rochester, N.Y., "The Motion-Picture Laboratory."

James W. Kaylor and A. V. Pesek, Color Corporation of America, Burbank, Calif., "Color Compensating Light Changer."

C. E. Beachell, National Film Board of Canada, Ottawa, Ont., "A Plotting Device for the Animation Stand."

Harry P. Brueggemann, Color Corporation of America, Burbank, Calif., "Electronic Light-Change Device."

THURSDAY AFTERNOON—High-Speed Photography

John H. Waddell, Wollensak Optical Co., Rochester, N.Y., "Survey of Photographic Principles of the Study of Motion as Established by the Old Masters With a Comparison of That Which Is Being Done Today."

Harry L. Parker, American Speedlight Corp., N.Y., "History of Electric Flash Lamps."

H. E. Edgerton, Robert Bonazoli and J. T. Lamb, Massachusetts Institute of Technology, Cambridge, Mass., "Duration and Peak Candlepower of Some Electronic Flash Lamps."

N. W. Rodelius and R. W. Thickens, Armour Research Foundation, Illinois Institute of Technology, Chicago, "The Simultaneous Recording of Mechanical and Electrical Events With the 16mm Fastax Camera."

C. C. Rockwood and W. Harvey, Chicago Midway Laboratories, Chicago, "Stroboscopic Lamp Using High Repetition Rate One-Joule Pulser."

Allen M. Erickson, Naval Ordnance Laboratory, White Oak, Md., "A Portable Timer for Instrumentation Photography."

FRIDAY MORNING—(Concurrent Sessions)

————High-Speed Photography

C. C. Rockwood and Richard M. Kuniyuki, Chicago Midway Laboratories, Chicago, "Duo Flash Photography."

David Grossman, Army Chemical Center, Md., "Precision Cut-Off and Braking of Fastax 8mm and 16mm Camera at High Speeds."

Charles C. Everett, International Harvester Co., Melrose Park, Ill., "High-Speed Photography in the Development of Diesel Engines."

George E. Merritt, U.S. Naval Proving Ground, Dahlgren, Va., "Uses of Photography in Ballistic Measurement."

Howard Betts, Albert Subach, Vanguard Instrument Co., Valley Stream, L.I., and C. A. Jantzen, Photographic Analysis Co., Clifton, N.J., "Quantitative High-Speed Motion-Picture Film Analyzer."

————Television

J. V. L. Hogan, Consultant, N.Y., "The Early Days of Television."

Richard S. O'Brien, Columbia Broadcasting System, N.Y., "CBS Color Television Staging and Lighting Practices."

H. M. Gurin, National Broadcasting Co., Inc., N.Y., "Color Television Light Sources."

E. T. Percy and T. G. Veal, Research Laboratories, Eastman Kodak Co., Rochester, N.Y., "Subject Lighting Contrast of Color Motion Pictures for Television."

James L. Lahey, Dage Electronics Corp., Beech Grove, Ind., "Television Camera for Film and Studio Use."

F. Cecil Grace, Allen B. Dumont Laboratories, Inc., Clifton, N.J., "Electronic Shutter in Television Film Pickup."

FRIDAY AFTERNOON—Televison Session

Axel G. Jensen, Bell Telephone Laboratories, Murray Hill, N.J., "The Evolution of Modern Television."

H. C. Oppenheimer, U.S. Army Signal Corps, Washington, D.C., "Applications of Television to Military Operations."

Sherman Atwood, National Broadcasting Co., Inc., N.Y., "The Design and Construction of a Color Television Mobile Unit."

J. M. Brumbaugh and R. O. Drew, Radio Corporation of America, Camden, N.J., "Improved Techniques for Television Recording With Ultraviolet Photography."

E. D. Goodale, National Broadcasting Co., Inc., N.Y., "Color Kinescope Recording."

Otto Wittel, Camera Works, Eastman Kodak Co., Rochester, N.Y., "A Continuous Projector for Television."

Laboratory and Jones was appointed chief physicist and held that position until he retired.

During the first World War, Dr. Jones was commissioned a lieutenant in the United States Naval Reserve Force in charge of camouflage investigation. In World War II he devoted his energy unsparingly to the work of the National Defense Research Council and the Office of Scientific Research and Development. He also acted as a member of the War Emergency Committee-Z52 of the American Standards Association.

Besides his service on the committees of this Society, he served for many years on various committees of the Illuminating Engineering Society, and the Optical Society of America and other scientific organizations. He was chairman of the Z38 Section Committee, Photography, of the American Standards Association from 1940 to 1950. When he retired as chairman of this Committee in 1950, it was announced at a luncheon meeting in his honor that a total of 135 photographic standards had been prepared by his committee and a bound volume containing all of the standards was presented to him. One of the significant accomplishments of his committee was the standardization of a method for determining photographic speed and speed number in 1946.

Dr. Jones was the recipient of many honors for his outstanding contributions to photographic theory and practice. In 1926, the Association of Scientific Instrument Makers of the United States recognized a paper by him as the best instrument paper offered for publication in the *Journal of the Optical Society of America* and the *Review of Scientific Instruments.* In 1935 as coauthor with J. H. Webb of a paper "Reciprocity-Law Failure in Photographic Exposure," he received the Journal Award of the Society of Motion Picture Engineers. This Society awarded him its highest honor, the SMPE Progress Medal, in 1939 "in recognition of the outstanding character of his scientific researches in the field of photography, with particular reference to his investigations of sensitometric procedures, his studies of photographic terminology, and his determinations of the criterion of pictorial excellence achieved by photographic processes."

The Optical Society of America, of which he was president in 1930 and 1931, presented their Frederic Ives Medal to him in 1943, "in recognition of outstanding achievements in photographic research with special reference to sensitometric processes, photographic print quality, and motion photomicrography of crystals, of leadership in photographic terminology, and of leadership in the preparation of an excellent and comprehensive report on colorimetry."

In January 1949 Dr. Jones was notified that he had been awarded the Progress Medal of the Royal Photographic Society of Great Britain for 1948. This medal, the highest honor of this Society, was given to him "in recognition of his valuable and outstanding contributions to the use of photographic sensitometry in the manufacture and control of photographic materials and in our understanding of their utilization."

On May 3, 1949, he gave by invitation

the 16th Hurter and Driffield Memorial Lecture for which he received the Hurter and Driffield Medal of the Royal Photographic Society. In July 1949 he was honored again by that Society when its Council conferred upon him an Honorary Fellowship.

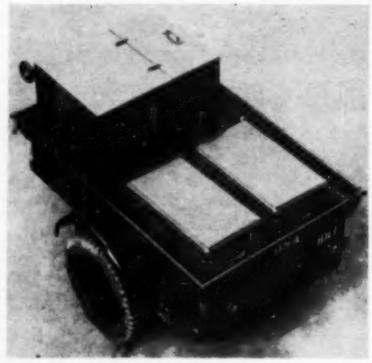
The Photographic Society of America conferred their Honorary Fellowship on Dr. Jones in 1949. In 1950 they awarded him their Progress Medal "for outstanding contributions to photographic science and practice, especially in the field of sensitometry." In 1953 he received the PSA Journal Award for 1952 for his paper "The Psychophysical Evaluation of the Quality of Photographic Reproductions."

On May 4, 1954, Dr. Jones was one of 26 members of the Society of Motion Picture and Television Engineers who were awarded Service Certificates in recognition of their services for more than 30 years to that Society and to the motion-picture industry.

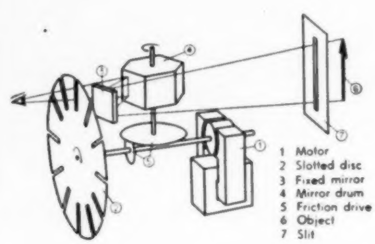
Dr. Jones was always characterized by the great energy with which he attacked the problems of scientific research. He had a calm, orderly, and searching mind, and an insatiable desire for learning the truth about every subject he studied. The knowledge of the physics of photography was advanced significantly by the work of Loyd Ancile Jones throughout the more than forty years that he labored in this important field. The field of motion-picture engineering has sustained a great loss by his passing, but his published researches will long provide a valuable reference in this and allied fields.—*Glenn E. Matthews*

New Products

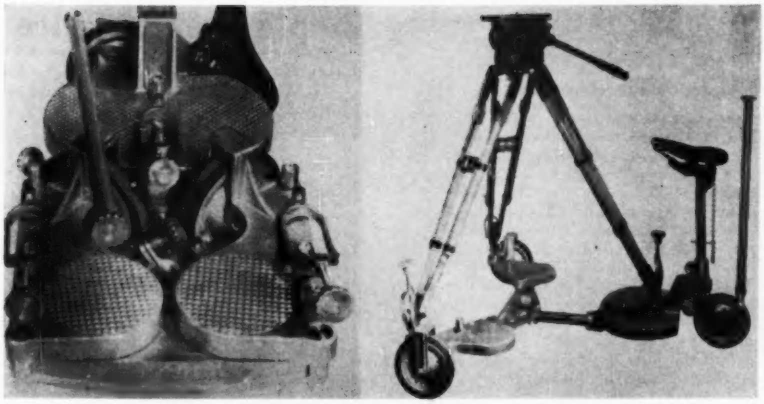
Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



A 1½-kw lighting set fitted into a ¼-ton, 2-wheeled standard Army cargo trailer has been developed by the Electrical Engineering Dept. of the Engineer Research and Development Laboratories, Fort Belvoir, Va. Also, there are 3-kw and 5-kw sets which fit into a ¾-ton trailer. Interchangeability of components and containers between sets, lightness and compactness of packing and ease of assembly and disassembly were the bases for design. It is reported that the largest set can be assembled by two untrained men in 75 min. and disassembled in 65 min, compared with 5 and 10 hr required for previous equipment. Splicing and pole climbing have been eliminated. Where possible, sockets, plugs and receptacles have been made part of the cables and lamp cords.



The Kern Swiss Super-Stroboscope is a new precision tool for the observation and photography of rapidly occurring phenomena of periodic as well as aperiodic natures. The light placed behind the object is limited by a slit. It first hits a fixed mirror which reflects it to a rotating drum of six mirrors driven by a motor and is finally directed through a revolving disk with from two to 100 slots coupled to the same motor. A special regulator changes the motor speeds from 500 to 2500 rpm, while the transmission ratio between disk and mirror drum can be adjusted from 1:45 to 1:90. Up to 100 images/sec are visible through the consecutive slots which are laid side by side at regular intervals. An analysis of almost any type of movement can be made by changing the width of the slit, the speed of the motor, the transmission ratio and the number of slots. By stopping the mirror drum the instrument can be converted into a simple stroboscope. The new instrument, made by Kern & Co. of Switzerland, is distributed here by Karl Heitz, Inc., 150 W. 54 St., New York, and priced at $995.



A new, collapsible, three-wheel dolly, has been designed for easy transport to field and location jobs, measures 45 × 46 in. assembled and 18 × 12 × 36 in. to fit into the carrying case. It is equipped with rear wheel for steering, or for locking into position for straight dollying. It mounts a baby tripod and provides for both the cameraman and his assistant to ride. It is available at $300, with $30 additional for the carrying case, from Camera Equipment Co. 1600 Broadway, New York 19.

A new version of the Lawrence Color TV Tube is shown by Prof. Ernest O. Lawrence. It is reported that the Chromatron PDF 21-3 incorporates the latest design developments, including a radiation-suppressed Chromapac (the color grid structure at the front of the tube), that the tube gives a true rectangular picture of 14½ × 11 in. and that the same envelope will accommodate a picture size of 210 sq in. The rectangular shape of the tube is reported to allow a cabinet as much as 20% smaller than would be the case with a round tube. The tube is 25 in. long.

The Lawrence tube is a single-gun, post-deflection focusing tube. Samples are being supplied to set and tube manufacturers. Chromatic officials have forecast that mass production will permit an eventual price below $100. Besides its West Coast Development Laboratory at Oakland, Calif., and its manufacturing plant at Emeryville, Calif., Chromatic Laboratories, Inc., has a laboratory in the Paramount Bldg., 1501 Broadway, New York 36, from which is available a reference booklet covering the designs and possibilities of the tube.

A development and licensing organization, Chromatic Television Laboratories is jointly owned by Paramount Pictures Corp. and Gaither and Company which is a partnership of Prof. Lawrence and H. Rowan Gaither, Jr., San Francisco.

Kodak Photographic Materials and Light Filters for the Laboratory is a new catalog available from the Industrial Photographic Div., Eastman Kodak Co., Rochester 4, N.Y. The catalog is divided into categories of materials for: (1) general photography and photomicrography, (2) specialized recording of radiation, (3) general spectrochemistry, (4) deep ultraviolet, (5) infrared, (6) autoradiography and nuclear particle tracks, (7) electron imagery, (8) finest image detail, (9) modifying spectral distribution, (10) attenuating light and (11) other photographic techniques.

Still Photography Standards

Below are listed the numbers and titles of recently approved American Standards in the field of still photography. Additional listings of such standards will be published in the *Journal* from time to time, as they are made available, as

a service to those readers who maintain an active interest in still as well as motion-picture photography. Previous enumerations of PH4 appeared in the July 1953 *Journal*, p. 82, and in the January 1954 *Journal*, p. 91.

Photographic Films, Plates and Papers, PH1

Dimensions for Molded-Type Cores for Photographic Film and Paper Rolls, Ph1.13-1953 (Rev. of Z38.1.48-1947)
Dimensions for 35-Millimeter Film Magazines for Still Picture Cameras, Ph1.14-1953 (Rev. of Z38.1.47-1946)
Dimensions for Industrial X-ray Sheet Film (Inch Sizes), Ph1.15-1953 (Rev. of Z38.1.25-1947)
Dimensions for Graphic Arts Sheet Film (Inch Sizes), Ph1.16-1953 (Rev. of Z38.1.26-1947)
Dimensions for Medical X-ray Sheet Film (Inch and Centimeter Sizes), PH1.17-1953 (Rev. of Z38.1.27-1947)
Dimensions for Professional Portrait and Commercial Sheet Film (Inch Sizes), PH1.18-1953 (Rev. of Z38.1.28-1947)

Photographic Processing, PH4

Temperature for Photographic Processing Solutions, PH4.5-1953 (Rev. of Z38.8.1-1944)
Method for Converting Weights and Measures for Photographic Use, PH4.6-1953 (Rev. of Z38.8.2-1945)
Method for Determining the Thiosulfate Content of Processed Photographic Film, PH4.8-1953
Specification for Photographic Grade Sodium Thiosulfate, Anhydrous, (Anhydrous Hypo), PH4.250-1953 (Rev. of Z38.8.250-1949).
Specification for Photographic Grade Sodium Thiosulfate, Crystalline (Crystal Hypo), PH-4.251-1953 (Rev. of Z38.8.251-1949)
Specification for Photographic Grade Ammonium Thiosulfate, 60-Percent Solution (Ammonium Hypo Solution), PH4.252-1953
Specification for Photographic Grade Ammonium Thiosulfate, (Ammonium Hypo), PH4.253-1953

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, c/o Penning, 435 E. 74th St., New York 21, N.Y.

Motion-Picture Cameraman, Film Editor: 15 yrs experience all phases of motion-picture work, including research; 3 yrs TV film operations. Developer of Panoramascope wide-screen motion-picture system. Active Member of SMPTE. Desires position with industrial or educational film producer as first cameraman or film editor. Wire: Frank E. Sherry, Jr., 207 West Rusk St., Tyler, Tex.

Photographic Engineer: M.A.; age, 28. Desires challenging, responsible position where technical knowledge and ingenuity will be fully utilized; 8 yrs diversified experience pertaining to the photographic process, with particular emphasis on photographic instrumentation for data recording. Background includes a thorough working knowledge of electronics, the graphic arts, color, machine-shop practice, high-speed photography, etc. Presently engaged as a senior member of a well-known industrial research organization where all kinds of photographic techniques are used as research and service tools. Willing to relocate. Write: P.O. Box 259, New York 36.

Cameraman and special effects producer: For news, educational or advertising films; technical and musical education; camera and 35mm film strip and color development experience. Write: Vitold Bredshnyder, 812 N. Monroe St., Monroe, Mich.

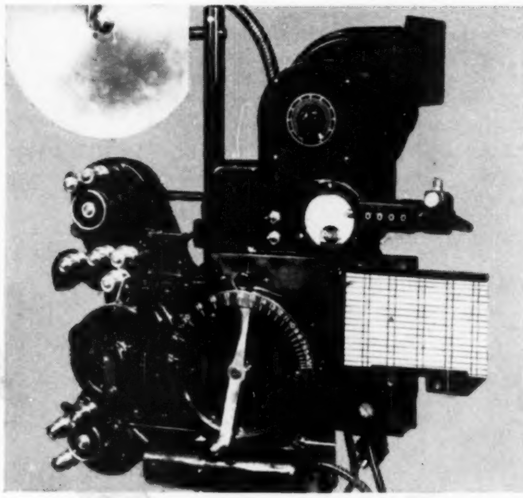
Positions Available

16mm Printers, Color Timer, Negative Conformer: Permanent positions for qualified, experienced personnel. Company benefits. Send complete information and small photograph to Byron, Inc., 1226 Wisconsin Ave., Washington 7, D.C.

Photographer (Motion-Picture Animation), GS-9: Require 5 yr experience in photography, 4 yr of it as animation photographer in production of cel animation work in motion-picture production. Also included must be at least 1 yr in technical animation photography. $5060/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Chicago Film Studio needs man to take charge stop-motion and animation dept. Must be experienced, able to direct title and animation cameramen. Write giving experience and salary desired. Filmack Corp., 1327 S. Wabash Ave., Chicago 5, Ill.

Permanent Employment: Open for mechanical engineers or physicists with at least 1 yr optics experience. Knowledge of camera mechanism, auxiliary timing apparatus and control equipment, precision camera mounts, photography and a general overall knowledge of fundamental optics highly desirable. Positions are located near Cocoa, Fla., at RCA Missile Test Project. Send completed résumés or requests for applications to Harold D. Storz, Employment Sec., RCA Service Co., Box 11, O M U, Patrick AFB, Fla.



Continuous Printer Model 5205 — adapts for color films, black-and-whites, TV films and for the new 32mm process (printing two 16mm films simultaneously).
Model 5205 from $3,795

New 300-watt Super-High Intensity Printer Lamp is 194.8 foot-candles brighter than any other 300-watt printer. Included on all new Model 5205 printers, this lamp may be added to B&H printers now in the field. $595

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NEXT MONTH'S JOURNAL will lead off with these papers:

"CBS Color-Television Staging and Lighting Practices," by Richard S. O'Brien

"Color-Television Light Sources," by Herman M. Gurin

Single copies of the August Journal, or copies in lots, will be sold at a cost considerably reduced from the usual single-copy price to anyone whose order is received by August 5. Such orders will be added to the regular print order of the Journal, and the end-of-the-run economy will be computed to pass on the saving for these special pre-publication orders.

Meetings

National Audio-Visual Convention and Trade Show, Aug. 1–4, Conrad Hilton Hotel, Chicago.

University Film Producers Association, Annual Meeting, Aug. 16–20, Ohio State University, Columbus, Ohio.

Biological Photographic Association, Annual Meeting, Aug. 25–27, Chalfonte-Haddon Hall, Atlantic City.

Illuminating Engineering Society, National Technical Conference, Sept. 13–17, Chalfonte-Haddon Hall, Atlantic City, N. J.

2d International Symposium on High-Speed Photography, Paris, September 22–28, 1954. Arranged by the Association Française des Ingenieurs et Techniciens du Cinéma. Applications or inquiries should be addressed to the Secretary of the Organizing Committee, P. Naslin, Laboratoire Central de l'Armement, Fort de Montrouge, Arcueil (Seine), France.

National Electronics Conference, Tenth Annual Conference, Oct. 4–6, Hotel Sherman, Chicago.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting Oct. 11–15, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

The International Commission on Illumination is to hold its next international conference in Zurich, Switzerland, June 13–22, 1955. Offers of papers should be addressed to the Chairman of the Papers Committee (A. A. Brainerd), 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (next year), Lake Placid Club, Essex County, N.Y.

Photographic Society of America, 1955 Convention, Oct. 5–8, 1955, Sheraton-Plaza Hotel, Boston, Mass.

National Electrical Mfrs. Assn., Nov. 8–11, Haddon Hall Hotel, Atlantic City, N. J.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April Journal.

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OF THE

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Raytone Screen Corp.
Reeves Sound Studios, Inc.
S.O.S. Cinema Supply Corp.
SRT Television Studios
Shelly Films Limited (Canada)
The Stancil-Hoffman Corporation
Technicolor Motion Picture Corporation
Terrytoons, Inc.
Titra Film Laboratories, Inc.
United Amusement Corporation, Limited
Wenzel Projector Company
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.
Wollensak Optical Company